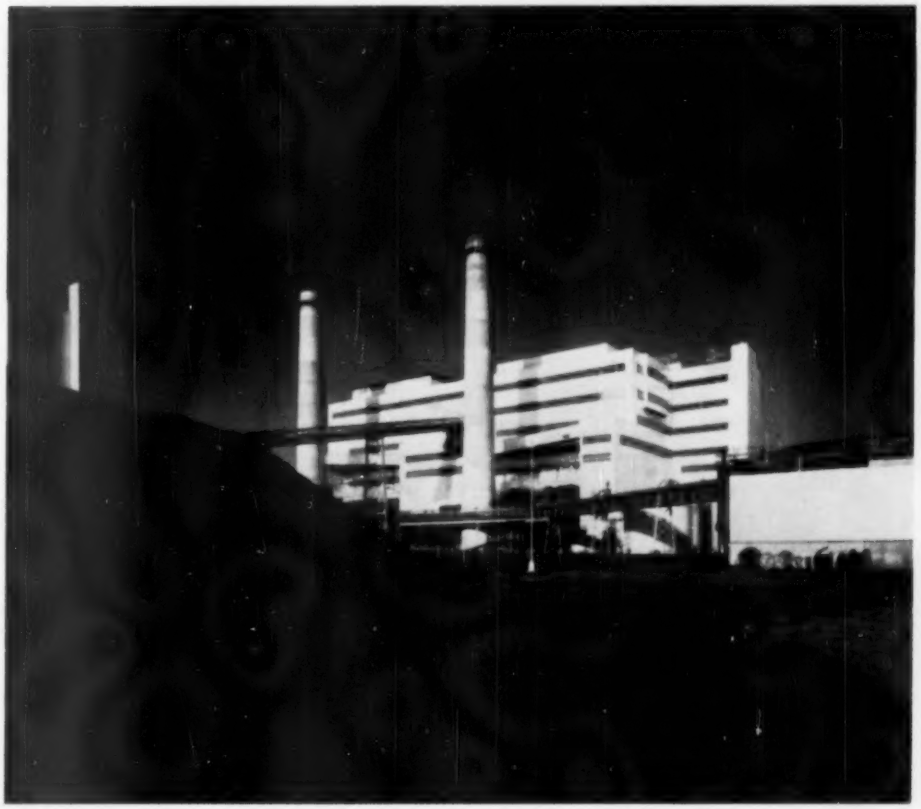
Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION



September 1960

Furnace Explosions

Generating Station Automation

Remote Burner Control and Flame Protection

Power Plant Clinic

Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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COVER PHOTO

Impressive shot of the Eddystone Station of Philadelphia Electric, home of the highest pressure steam generator yet built.

volume 32 *number 3* **September 1960**

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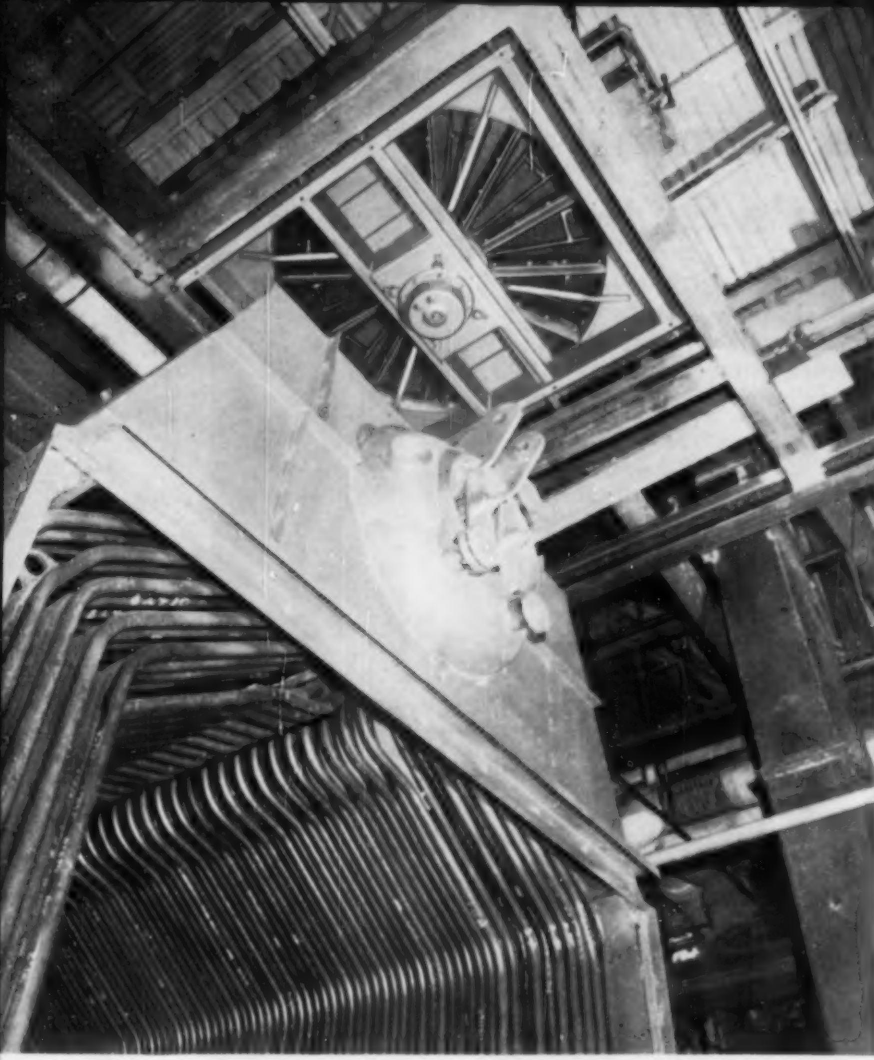

The Ljungstrom Air Preheater at the B. F. Goodrich Company Shelton Plant is installed directly over the 65,000 lb/hr Wickes boiler. Flue gas leaving the boiler at 615°F passes through the circular rotor, which absorbs the heat and releases it into the incoming air. Preheated combustion air improves combustion, makes fuel burn cleanly. This Package Air Preheater was factory-assembled, and requird only 100 manhours to install.

At B. F. Goodrich Co.'s Shelton Plant

Air Preheater boosts combustion air temperature 345°F...gives 6% more thermal efficiency

"Only a Ljungstrom® Air Preheater, with its continuous regenerative principle, could meet our requirements", says A. G. Sandomirsky, Manager of Engineering at the B. F. Goodrich Company, Shelton, Conn., plant. "We produce foam rubber 24 hours a day, five and six days a week. With an Air Preheater we can meet process steam requirements more economically, and an Air Preheater helped us to justify the installation of high efficiency, high pressure equipment for by-product power generation."

Here's why the Shelton plant meets its requirements best with a Ljungstrom Air Preheater:

1. Ljungstrom is the most efficient heat exchanger you can buy. The Ljungstrom rotor revolves continuously through the flue gas and incoming air, thus absorbing heat and releasing it *from the same surface*. Since the heat doesn't have to pass through anything, each inch of rotor surface is as efficient as one foot of a tubular recuperator.

2. Ljungstrom is the most reliable heat exchanger you can buy. All heat exchange elements pass through the entire air and gas streams. The temperature of the elements in the coolest region – where fresh air enters – is actually an average of the gas and air temperatures, so it's consistently higher than the coolest point in a recuperative heat exchanger. Result: no cold spots, less chance of moisture formation.

3. Ljungstrom is easiest to maintain. You can inspect it – and clean it–while it's running. Heat exchange elements are divided into modular baskets that can be replaced individually without disturbing the other elements. You can even reverse the elements if the surface has thinned on one edge, effectively doubling the life of the heat exchange surface.

For more information on the Ljungstrom continuous regenerative principle, or on the Air Preheater that meets your requirements, phone MUrray Hill 2-8250 or write to The Air Preheater Corporation.

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.

new Yarway Unit Tandem Valve

for blow-off service up to 665 lbs. WSP ...provides proven Yarway Unit Tandem dependability for medium pressure installations. Streamlined, light in weight, easy to operate, tight sealing, with minimum maintenance.

Ask for free Bulletin B-435, Supplement A

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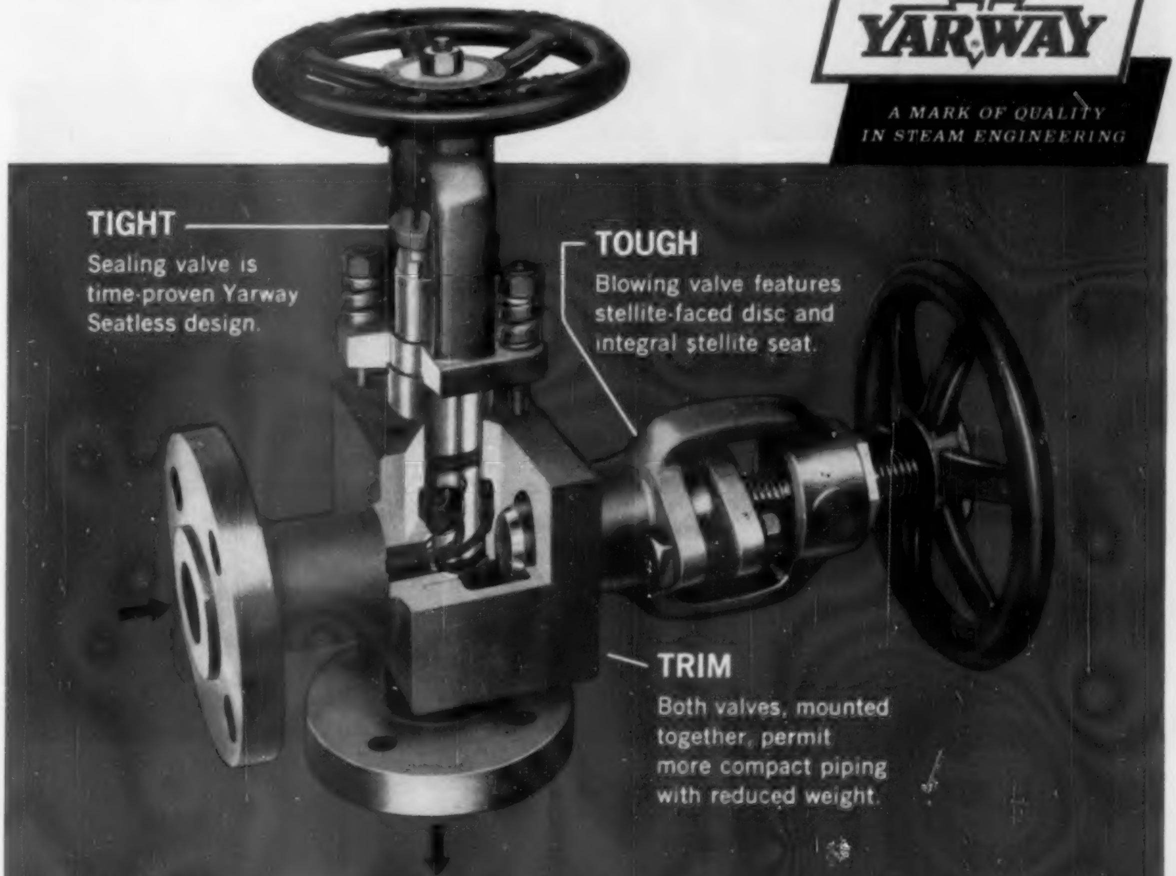
A MARK OF QUALITY IN STEAM ENGINEERING



72 tons of *FLY ASH* collected a day!

GREEN'S AERODYNE HELPS SOLVE CONSOLIDATED EDISON'S FLY ASH PROBLEM

Installation of Aerodyne Units at Consolidated Edison's Hell Gate Electric Generating Station.

Green makes this AERODYNE mechanical dust collector, to collect fly ash and other dusts. Does this Green AERODYNE really work?

Well, let's quote a few words from Mr. J. J. Grob, Chief Performance Engineer, Mechanical Engineering Department, Consolidated Edison Company of New York, Inc.

QUOTE 1
Why used

"At Hell Gate Station two Aerodyne mechanical collectors were installed in the uptake flues of boilers No. 11 and 12 for removing the bulk of fly ash leaving the furnaces."

QUOTE 2
72 tons of fly ash per day

"The furnaces are slag tap and, of that ash which would otherwise be expelled to the electrostatic precipitators before entering the stack, the Aerodyne units, based on careful tests, remove approximately 72 tons of fly ash per day."

QUOTE 3
Satisfactory

"The operation of the Aerodyne mechanical collectors has been satisfactory and the life of the cones has greatly exceeded expectations."

We repeat, in all modesty — Green can help you solve FLY ASH and DUST collection problems.

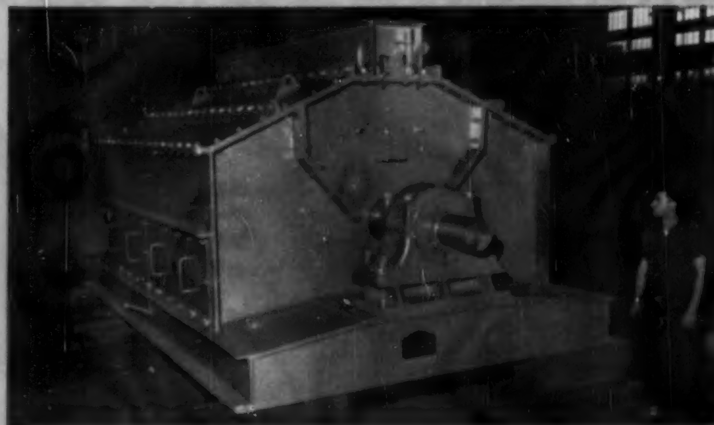
Why not write and ask us?

Green

THE GREEN FUEL ECONOMIZER CO., INC. **BEACON 3, NEW YORK**

DAILY GRIND ALWAYS UNIFORM

with Pennsylvania Reversible Hammermills



• Pennsylvania Reversible Hammermill for preparing bituminous coal for exact specifications of cyclone burner bin system, ready for shipment to large southern power plant.

Regardless of condition of coal or amount of hammer wear—Pennsylvania Hammermills are noted for producing a highly uniform product day after day.

Basic design and simple adjustments available to the operator on the spot make this possible.

Pin point adjustments of cage-hammer clearance (by ratchet wrench and worm gear assembly) compensate for hammer wear or coal condition.

Crushing action keeps fines to minimum. Free air impact crushing in upper zone prepares coal so there is little dredging of hammers through oversize in cage-bar zone. Results—uniform grinds day after day.

DOUBLE CRUSHING AREA: DOUBLE CAGE, BLOCK AND HAMMER LIFE

No other crushers give you so much more for your money. Pennsylvania Reversible Hammermills give double the crushing area—double the life of cage bars, breaker blocks and hammers. A flick of the switch; rotor is reversed and you are using a duplicate mill.

What's more, hammers need never be hand turned, and wear is kept uniform.

With adjustable cage assemblies, hammers can be worn much further while keeping grind uniform—with no falling off of tonnage.

FREE BULLETIN

Bulletin 1040, giving a full description of the design, construction features, operation and maintenance of Pennsylvania Reversible Hammermills, can prove profitable reading for you. Write for a copy today.

PENNSYLVANIA CRUSHER DIVISION
BATH IRON WORKS CORPORATION
WEST CHESTER, PENNA.

DOUBLE DIVIDEND!

Pennsylvania Bradford Breaker cleans coal as it crushes

Famous Pennsylvania Bradford Breakers not only crush and size run-of-mine coal—they automatically remove and discharge tramp iron and other refuse. This is just one of many features giving Pennsylvania world leadership for this type of crusher. Over 100 million tons of coal annually are prepared by Pennsylvania Bradfords in power plants everywhere.

For complete information, write and ask for Bulletin 3009.

* * *

Over 50 years concentrated experience in all types of material reduction makes Pennsylvania your best source of crushers and engineering advice and service. Call on Pennsylvania with your next crushing problem. Representatives from coast-to-coast.

PENNSYLVANIA

BATH-BUILT

CRUSHERS

'BUFFALO'– MOST COMPLETE LINE OF QUALITY HEATING, VENTILATING AND MAKEUP AIR UNITS

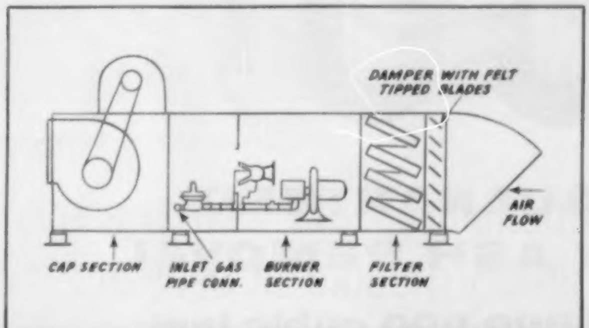
Whatever the air temperature requirements for your boiler room, turbine room or other plant areas, there's a 'Buffalo' Unit to give you permanent satisfaction. All embody the same quality engineering as the broad line of 'Buffalo' Mechanical Draft Fans.

For ventilation, you have 'Buffalo' Centrifugal, Propeller and Axial Flow Fans to choose from, depending on space, pressure and volume requirements. All are proven fans for specific design conditions, and may be used for supplying makeup air or exhausting.

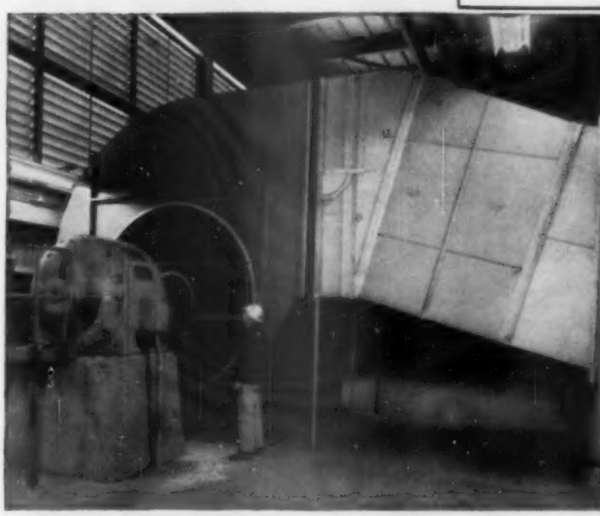
Sky Vent Power Roof Ventilators are efficient, weather-proof packages for economical installation without duct or floor space requirements. Available in 1,000 to 250, 000 cfm capacities, and can be arranged with heating coils and dampers for supplying makeup air.

New 'Buffalo' Direct Gas-Fired Makeup Air Units provide fresh, clean, tempered air without increasing boiler load. Units operate at virtually 100% thermal efficiency, with complete safety and freedom from attention. Can be built into Style H Sky Vent units. Also available with centrifugal blower head and accessories such as filters, dampers, etc.

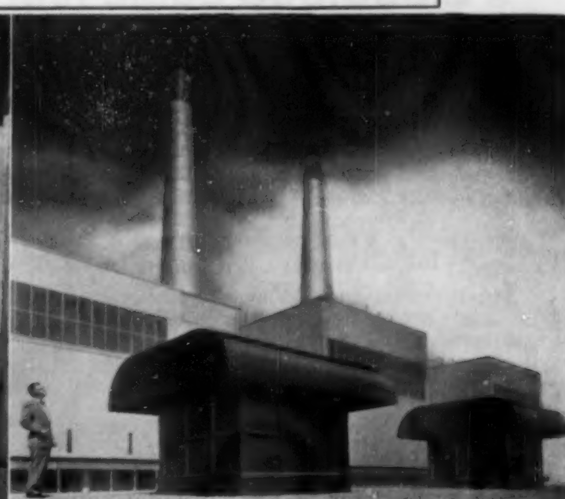
Write us about your heating, ventilating or makeup air problem—we'll give you details and recommendations promptly.



'Buffalo' Direct Gas-Fired Makeup Air Unit



'Buffalo' Type BL Ventilating Fan



'Buffalo' Power Roof Ventilators

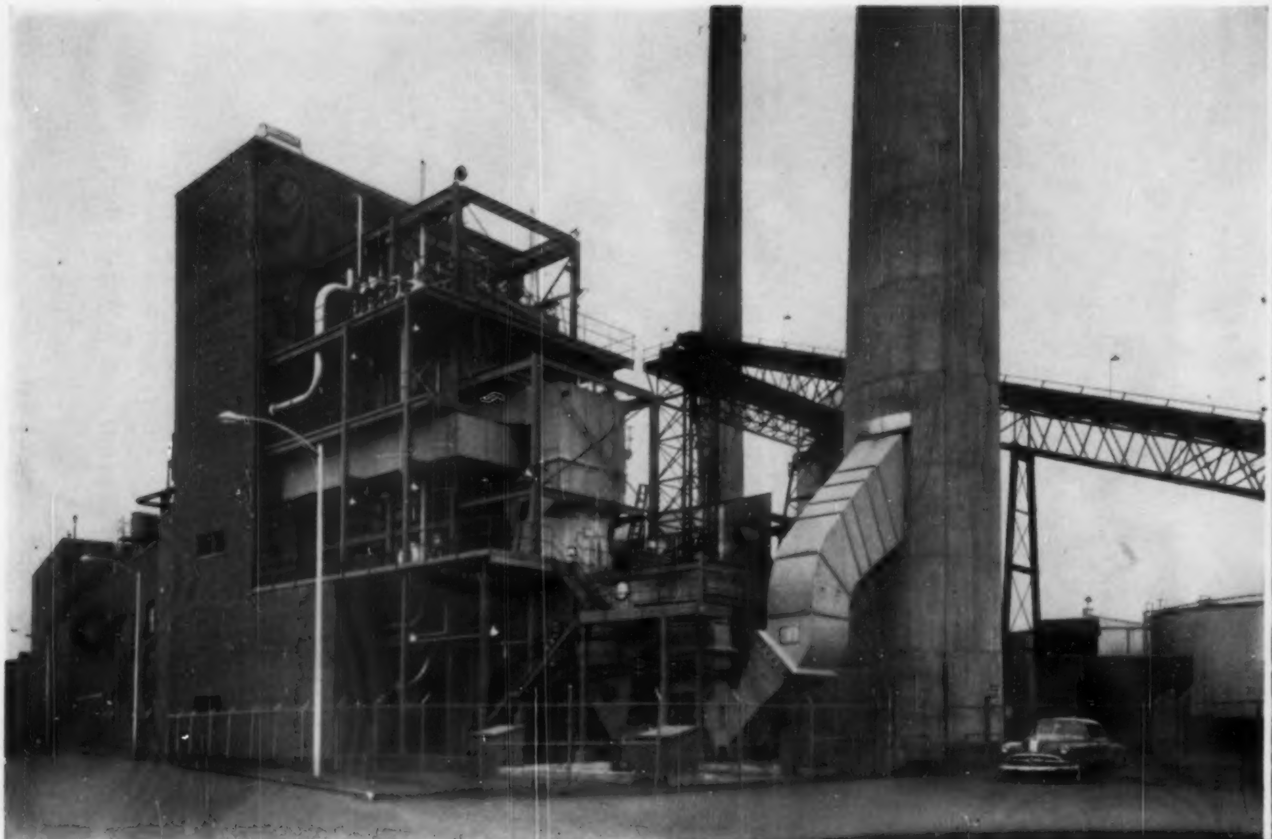
BUFFALO FORGE COMPANY
Buffalo, New York
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

'Buffalo' Air Handling Equipment to move, heat, cool, dehumidify and clean air and other gases.

'Buffalo' Machine Tools to drill, punch, shear, bend, slit, notch and cope for production or plant maintenance.

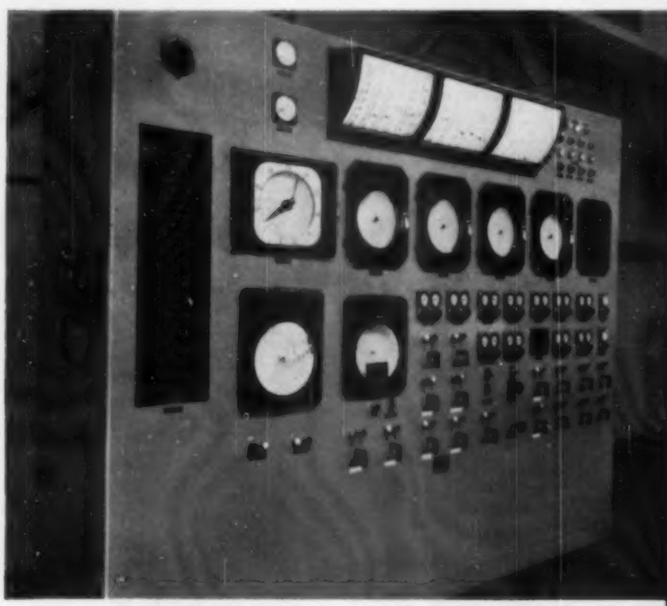
'Buffalo' Centrifugal Pumps to handle most liquids and slurries under a variety of conditions.

Squier Machinery to process sugar cane, coffee and rice. Special processing machinery for chemicals.



Except for the firing aisle and control room, Boiler Unit 7 is outdoors and subject to sub-zero temperatures. The unit delivers steam at 850 psig and 900°F to a 16,500-kw turbine-generator installed in the tall building (left) some 200 feet away.

Copes-Vulcan boiler control automatically balances output with demand at Taunton Plant



Eleven miniature Copes-Vulcan stations on this operating panel provide remote control of all processes with automatic-to-manual, or manual-to-automatic selection, with "bumpless" transfer. Automatic and manual loadings can be matched perfectly without going through a seal or reset position.

Diaphragm-type control valve (upper left) is used with Copes Type 3-L feedwater control. The valve features positioner, air lock, and side-mounted handwheel for emergency operation.

Designed for superior accuracy and long range dependability, Copes-Vulcan valves establish new standards of efficiency for pressure, temperature, flow, and level control.

Two versatile regulator valves are available for pressure standards from 125 through 2500 pounds. Diaphragm-type CV-D is designed for remote control service, can be direct or reverse acting, features excellent rangeability. Piston-type CV-P is designed for high-duty service, assures maximum power with precise positioning. **Write for Bulletin 1027.**

The two field mounted Copes-Vulcan indicating pressure transmitters (lower left) are used for feedwater (left) and fuel oil (right). Proportional action with pneumatic feedback is ideal for pressure regulating service.

Copes-Vulcan transmitters feature good repeatability. Standard output pressure is 3 to 15 psi for input bands of 1 to 100%. Outputs of 6 to 30 psi and 12 to 60 psi are also available. **Write for Bulletin 1036.**

Drive unit (right) for the inlet damper of the induced-draft fan is installed at ground level outdoors. Insulation, used for protection against adverse weather, is easily removed for inspection and maintenance of the unit.

Copes-Vulcan Drive Units permit remote positioning by automatic or manual signals. They may have linear, square, or square-root characteristics, or may be field-characterized.

Five models are available. All have 90-degree angular rotation and may be manually operated by a handwheel. **Write for Bulletin 1033.**

The Municipal Lighting Plant in Taunton, Massachusetts, selected Copes-Vulcan to provide Unit 7 with precision boiler control. Featuring simplicity of circuits and dependable accurate components, the Copes-Vulcan system automatically maintains a constant main steam-header pressure under varying demands. Peak loads reach 170,000 pounds per hour. Operation remains under fully automatic control down to 40,000 pounds per hour.

Unique combustion control includes skillfully designed circuits for fuel-loading report-back and fuel cut-back. Other controls assure constant furnace pressure, the correct ratio between steam flow and air flow, and a practically constant drum water level.

Temperatures and pressures regulated. Air-heater temperature, mill pressure, and steam temperature at the superheater outlet are accurately managed.

A complete line—a complete service. In addition to boiler control, the Copes-Vulcan line includes complete systems for fully automatic soot blowing, pressure reducing, and desuperheating. All are custom engineered. All are backed by more than 50 years of design experience.

Whether your boiler be large or small, power or process, Copes-Vulcan can provide a unit or a coordinated package to meet your requirements.

For the complete story, write for Bulletin 1065. Copes-Vulcan Division, Erie 4, Pennsylvania.

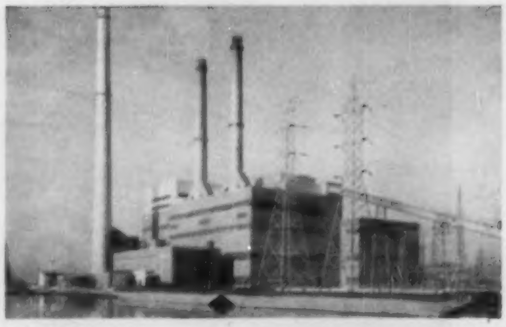
Copes-Vulcan Division

BLAW-KNOX

...in C-E Package Boilers

To a large extent, a utility company's operating cost is based on the efficiency and dependability of its steam generating equipment. With a major part of its business being with these power companies, C-E has developed a "utility-boiler" engineering philosophy that applies to *all* C-E products, large or small. You can be sure that *your* C-E boiler represents the latest thinking in thermodynamics and boiler design — and that materials and construction meet the most exacting standards. For *extra dependability*, specify "C-E."

Write to C-E for answers to your questions on C-E package and shop-assembled boilers. Catalogs are currently available on types VP, PCC and HCC.



3,900,000 lb/hr – A good example of utility-boiler engineering . . . C-E is currently at work on a new boiler for Commonwealth Edison Company, Chicago, which is the largest boiler ever ordered by an American utility company. The huge unit will serve a 510,000-kw generator and have a rated capacity of 3,900,000 pounds of steam an hour.

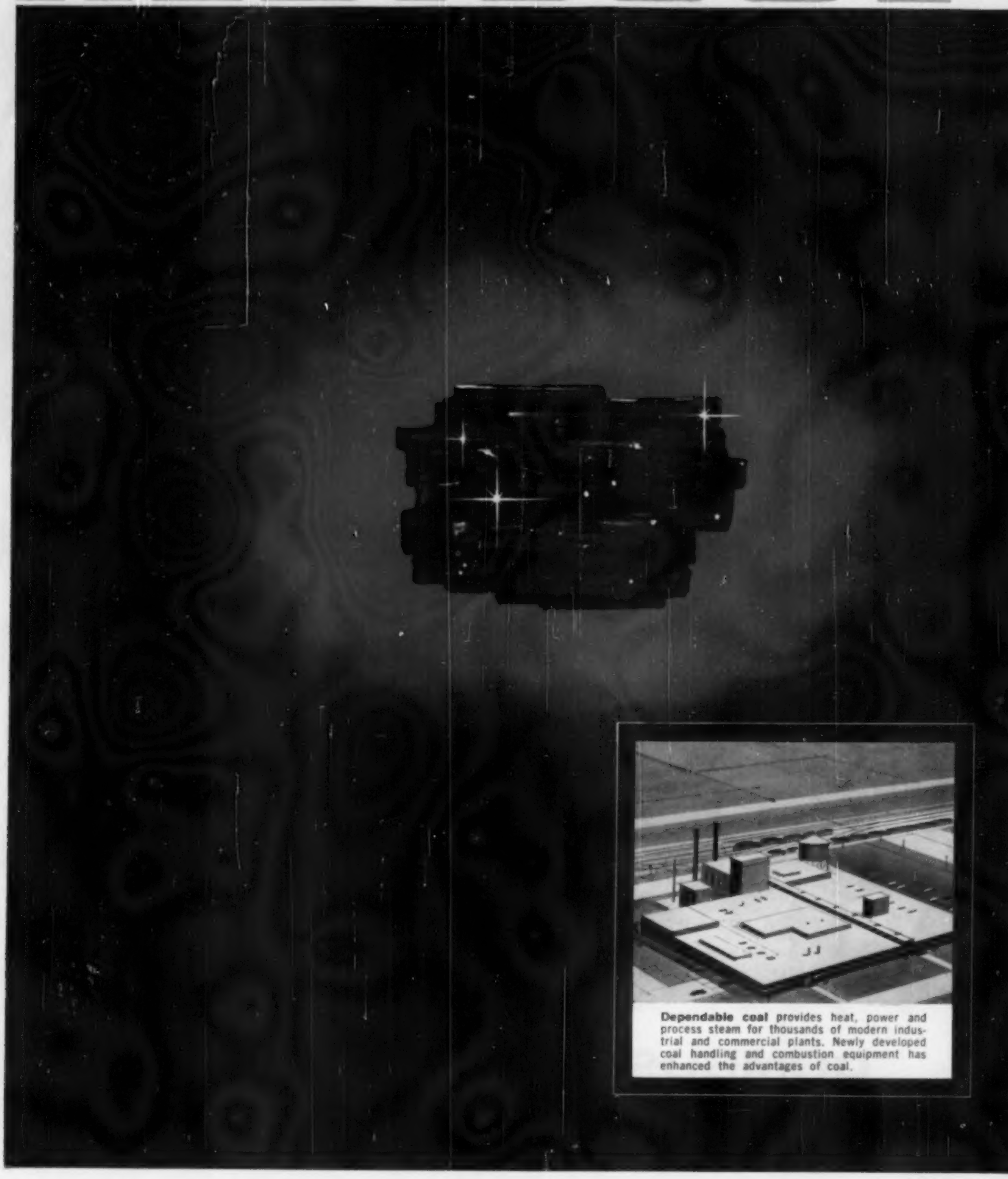
COMBUSTION ENGINEERING

Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.
Canada: Combustion Engineering-Superheater Ltd.

C-285

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

REDISCOV



Dependable coal provides heat, power and process steam for thousands of modern industrial and commercial plants. Newly developed coal handling and combustion equipment has enhanced the advantages of coal.

ER COAL!

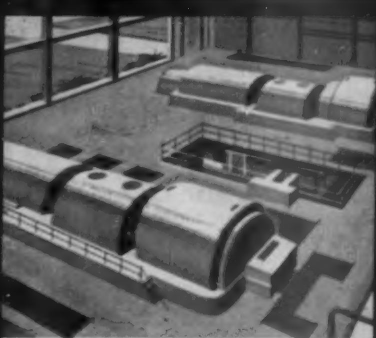
COAL IS RELIABLE for the constant production of steam for process and power

For over a century and a half, since the harnessing of steam, industrial America has been dependent upon coal for conversion to dynamic energy. Today, coal is still preferred by informed users in major industrial areas who count on its economy, efficiency and reliability.

Reliable—because coal's tremendous reserves assure abundant supply for *centuries, not decades*. More efficient and economical than ever before—benefits of constantly new technological developments in both the mining and use of coal. Reliability, too, in transportation of coal by Chesapeake & Ohio—and at low cost.

It will pay anyone faced with the problem of modernization to *rediscover coal*. Today or centuries from now there will be ample supply to outlive the life span of the finest combustion equipment.

Chesapeake and Ohio Railway
Terminal Tower • Cleveland 1, Ohio
Outstandability in Transportation



Electric Utilities depend upon the constancy of coal because electric power cannot be carried in inventory. It must be made when needed and used the instant it is made. Over 70% of the fuel consumed by utilities is coal.

C&O Fuel Service Engineers offer free consultation in C&O's market areas on any problem of combustion, application, equipment or plant arrangement. Write to: R. C. Riedinger, General Coal Traffic Manager, at the address above.

The Chessie Line, a 5,100-mile modern transportation plant, directly serves over 300 mines in America's richest bituminous coal reservoir with the finest fleet of 68,000 coal cars. Specify C&O routing for dependable delivery.

CHESSIE SERVES THE COAL BIN OF THE WORLD

Hall Industrial Water Report

VOLUME 8 SEPTEMBER 1960 NUMBER 5

How to Avoid Crash Programs

What caused your latest emergency crash program? Was water at the bottom of it? Did boiler tubes fail because of internal deposits or corrosion? Power plant down to clean turbine blades? Steam heat cut off for repair of leaking return lines? Air conditioning equipment shut down to clean condensers? Process gone sour due to poor clarification of water? In trouble with state authorities over contaminated waste water?

Crash programs to maintain production or to minimize losses caused by shutdowns for repairs or changes to improve water conditions are costly. They can be avoided if suitable water treating equipment is installed and effective water conditioning programs are adopted.

Hall Laboratories engineers are specialists. They can advise on equipment and set up water conditioning programs designed to give you trouble-free operation at low cost. And they can teach your operating men how to maintain the proper water conditions.

Stripper Column Deposits

During a routine boiler water conditioning service call at a New Jersey chemical plant Hall field engineer Frank Duesing spoke of plant-wide water service. Immediately, a plant chemical engineer suggested that Duesing look at a solvent recovery stripper column which was out of service because of heavy deposits on the bubble plates. The plant engineers had assumed that the deposits were composed of material picked up by the solvent and precipitated in the recovery equipment.

Duesing tested the deposit in dilute acid. The rapid evolution of carbon dioxide gas indicated that the material was made up largely of calcium carbonate. This meant that the hard raw water being used was responsible for the deposition. Duesing recommended acid cleaning of the column and substitution of zeolite-softened water, or preferably condensate, for the raw water. Zeolite-softened water was immediately available so this was used.

There has been no further deposition of calcium carbonate, although a little temporary trouble occurred when the solvent did become contaminated with catalyst. The previous experience led to quick identification of the material so that plant engineers could promptly stop the contamination.

Flood Causes Water Shortage

When floods produced a break in the dam of the municipal reservoir at a city in Ohio, all industrial city water users had to curtail consumption. A box company immediately made plans to keep their boiler operating by bringing water in tank trucks from a neighboring city. Unfortunately, there was no time to clean the tanks which had been transporting oil and salt water.

Hall field engineer Dale Holland arrived at the plant just before use of the contaminated water was started. After quickly analyzing the purchased water he set up a program of hourly testing, blowdown control and antifoam feed. He then helped the operators maintain good control during the emergency period. The quick action permitted trouble-free operation of the boiler despite oil contamination, harder water and abnormally high solids concentrations.

One of the plant operating men remarked that, in his opinion, no plant production would have been possible during the emergency without the help given by the Hall Laboratories engineer.

Deaerating Heater Trouble

Despite repeated recommendations of Hall field engineer Stan Ziarkowski to use sodium sulfite to protect the boilers from corrosion, the operators in an industrial plant did not get around to installing the necessary feeding equipment. There seemed to be no urgency because the boilers had operated for a long time without corrosion damage.

When Ziarkowski inspected the largest boiler, and found some pitting his concern grew. The situation was serious because this boiler was the only one which could carry the entire plant steam load. His concern increased when feedwater tests showed the concentration of dissolved oxygen to be much higher than normal for a deaerating heater.

The heater was inspected and cleaned. Nothing to account for poor deaeration could be found so it was put back in service. Again feedwater oxygen tests showed excessive concentrations. Another inspection was made at Ziarkowski's request and this time the vent condenser was opened. Here was the trouble. Many tubes were leaking, permitting water to pass through the heater without being thoroughly deaerated.

Vent condenser tubes were repaired. The use of sodium sulfite was started. Then all ran smoothly. What seemed to be an unnecessary move could have saved the replacement of more than one hundred fifty pitted boiler tubes and avoided production downtime.

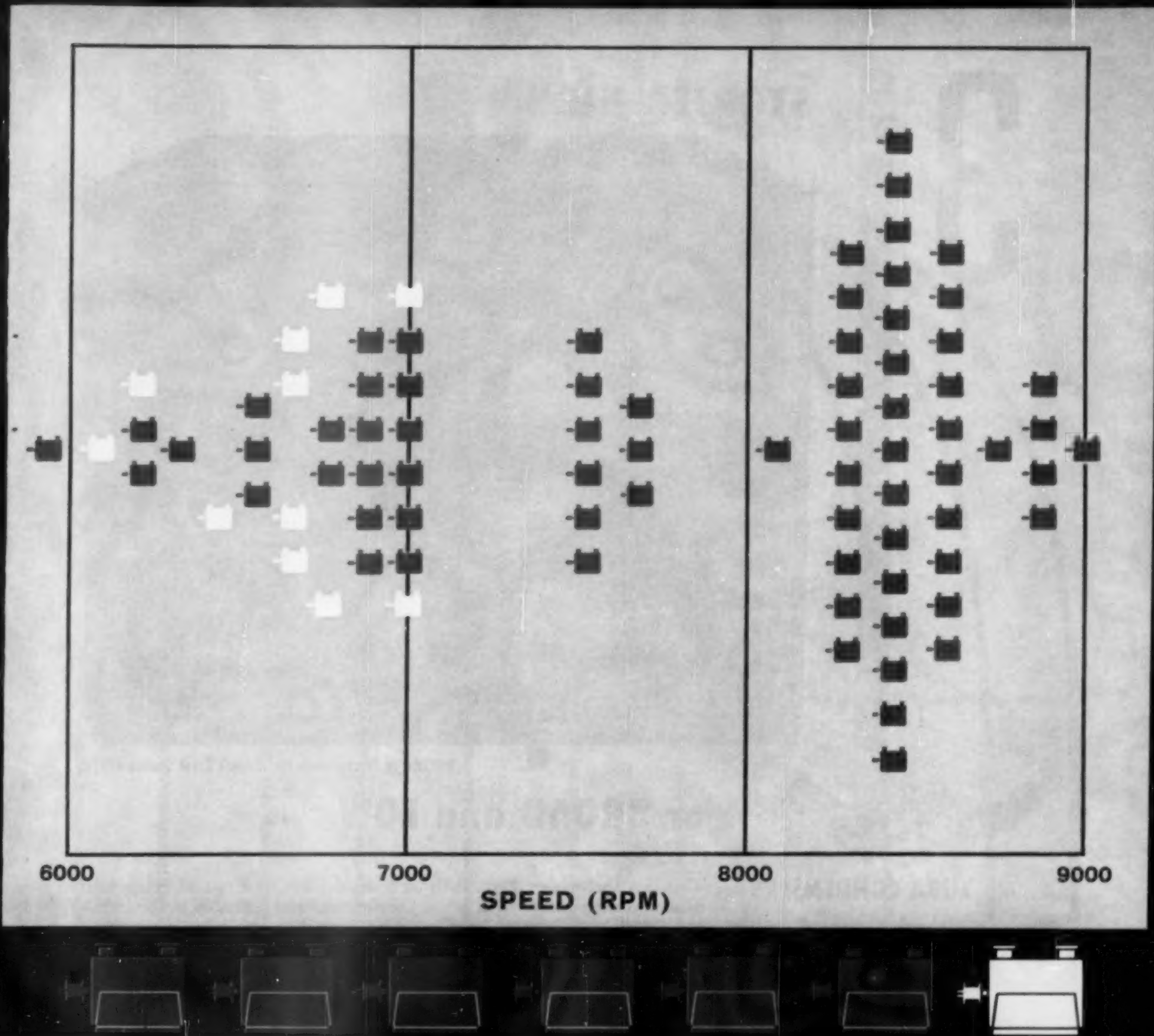
Water is your industry's most important raw material. Use it wisely.

How Consultants Solve Industrial Water Problems

There are no "stock answers" to industrial water problems. A new 24-page booklet, "Hall Laboratories—Industrial Water Consultants," describes the many ways industry can use water most economically. For a copy of this booklet, write on your letterhead to:

HALL LABORATORIES
HAGAN CENTER, PITTSBURGH 30, PA.
Consultants on Procurement, Treatment, Use and Disposal of Industrial Water

DIVISION OF **HAGAN** CHEMICALS & CONTROLS, INC.



WORTHINGTON MAKES 6 OUT OF 7 HIGH SPEED BOILER FEED PUMPS

The trend in boiler feed pumps today is to higher speeds. This provides the higher pressures needed in today's power generating equipment. An important side benefit is that it permits boiler feed pumps to be turbine driven at optimum turbine speeds. And it offers much better opportunity for standardization of equipment, including the benefit of fewer stocked parts.

In over 80 high speed boiler feed pump central station installations, above 6000 rpm, already made or on order, six out of every seven pumps are built by Worthington. And this includes two out of every three main-shaft-driven units.

Why does Worthington lead? Because of its design philosophy. It alone has taken these pumps to 9000-rpm speeds.

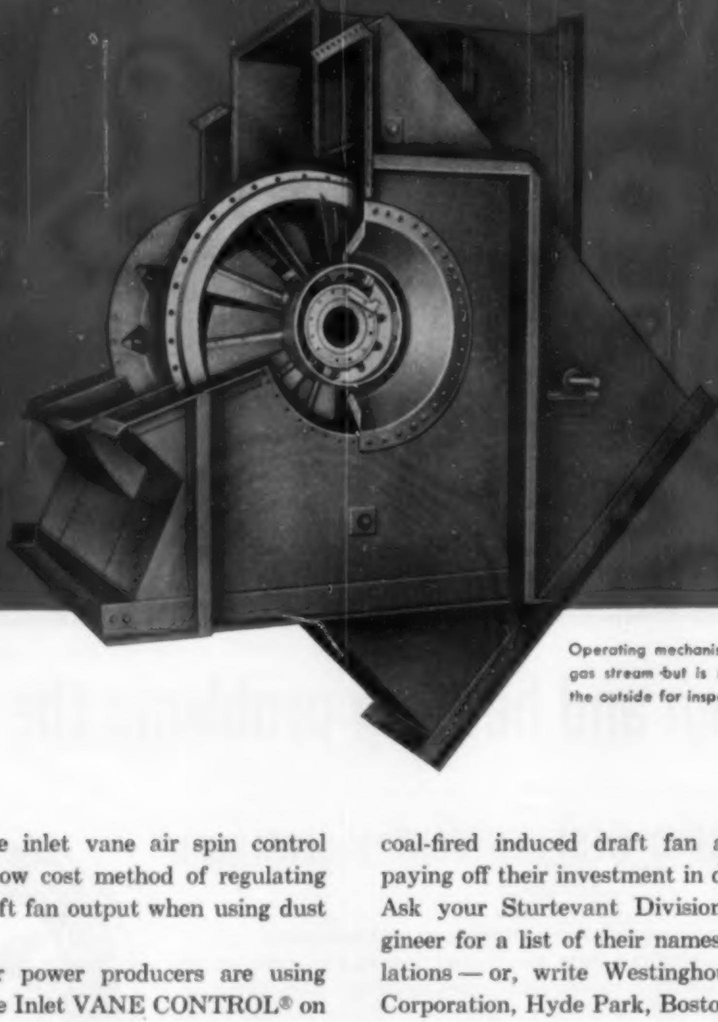
A Worthington design begins with minimizing shaft span, maximizing shaft diameter and keeping generous running clearances—all to reduce deflection and improve reliability. Next comes attention to critical areas: impellers are shrunk on shafts for strength and leakage prevention; metal-to-metal ring-type joints eliminate gasket failure; a balancing device compensates for axial thrust and special bearings eliminate vibration caused by oil-whip.

Other features, too, such as freedom for thermal expansion and machined twin volutes add to Worthington high-speed boiler feed pump reliability.

In a booklet just printed Worthington discusses "The ten most important features in boiler feed pumps today." From it you'll quickly understand why boiler feed pumps are now freed from the traditional 3600-rpm limitation. And you'll read basic design considerations that will help you in boiler feed pump selection. Write Worthington Corporation, Dept. 45-16, Harrison, New Jersey.

WORTHINGTON

Westinghouse Volume Control helps pay off fly ash dust control investments



Operating mechanism is shielded from the gas stream but is readily accessible from the outside for inspection and maintenance

Westinghouse inlet vane air spin control is a *proven* low cost method of regulating Induced Draft fan output when using dust arrestors.

Many major power producers are using Westinghouse Inlet VANE CONTROL® on coal-fired induced draft fan applications, paying off their investment in dust control. Ask your Sturtevant Division Sales Engineer for a list of their names and installations — or, write Westinghouse Electric Corporation, Hyde Park, Boston 36, Mass.

PLANTS AT HYDE PARK, MASS., LA SALLE, ILL., BERKELEY, CALIF.

YOU CAN BE SURE...IF IT'S Westinghouse

Watch "Westinghouse Lucille Ball-Desi Arnaz Shows" CBS-TV-Fridays

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EDITORIAL

A Moment's Thought

Labor Day this year presents a particularly grim picture. As a nation we are about to experience "the agonizing reappraisal" of our way of life and our conduct as a government while the presidential candidates battle it out. As an industry we find ourselves sharply reviewing our plant operating techniques and installing peaking capacity in the interim before the next big step—more automation—brings into general practice the larger units, the higher pressures, the higher temperatures we now have ready. As individuals any such reappraisal or review turns up areas of concern.

One of the most grievous concerns as we have seen it is the need to attract more soundly grounded young people into the industry. We stress this need because we know others see it and have expressed a worry about it. The emphasis on automation could create an unbalance. Our English contemporary Capricorn in his July 1, 1960 column stressed "I hope the university and college teachers always bear in mind the essentially practical nature of the profession and the industry. Engineering, like politics is the art of the practical; and although it is making more and more use of sciences, we are long way off reducing all engineering to a scientific basis. If we ever reach that computer's paradise engineers will have worked themselves out of a job." Amen, we say.

Preventing Furnace Explosions*

By WILLIAM L. LIVINGSTON†

Combustion Engineering, Inc.

A satisfactory system which can reliably prevent furnace explosions will include many interrelated devices and subsystems. This paper discusses the conditions that will produce a combustion chamber "puff" and establishes the proper relationship of the flame detector to a system capable of preventing those conditions. The scope for development work which should be done before a furnace protecting system can be assembled is presented.

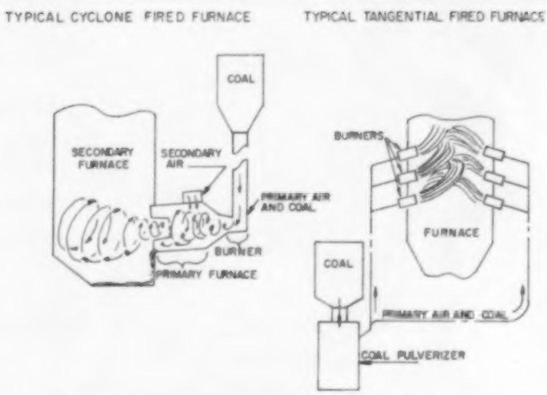


Fig. 1—Schematic arrangement of common firing systems

FURNACE explosions are dangerous and expensive events. The increasing number, size, and restoring costs of commercial fire-boxes are placing added importance on the problem of safely burning liquid, gaseous and solid fuels within them. The simultaneous increase in the need for high unit availability, since investments are more concentrated in large single units, demands that the unit be kept operating except for legitimate reasons. Unnecessary trip-outs not only force costly outages, they require the furnace to go through additional involved and relatively hazardous light-off operations.

Furnace Explosions

A furnace "puff" is the result of an extremely high heat release rate occurring throughout a sizable portion of the unit. Damage is inflicted when the pressure created by the rapidly heated gases exceeds the rupturing pressure of the furnace container.

Although furnace explosions on large utility boilers usually occur in only a part of the unit, the "puff" pressures seldom equalize throughout the other large gas paths quickly enough to prevent damage. Coal dust explosions, for example, can generate pressures at a 2000 psig/second rate (1)[1]. Local explosions, therefore, may cause local damage, but substantial indirect effects.

Commercial fuel and air explosions rarely generate tremendous pressures. The maximum puff pressure which can be generated with an ideal bituminous coal dust explosion is 88 psig/operating atmosphere (1). Pulverized coal supply systems are generally designed to withstand 50 psig/operating atmosphere (2)

Furnace containers designed to the National Board of Fire Underwriters Standard can withstand 0.25 psig above normal operating pressure with a deflection at the buckstays of not more than 1/200 of the span. Thus, a furnace explosion does not usually have to generate very high gas pressures to inflict damage. The costs involved in constructing a furnace container to withstand explosion pressures are generally prohibitive.

Conditions Causing Furnace Explosions

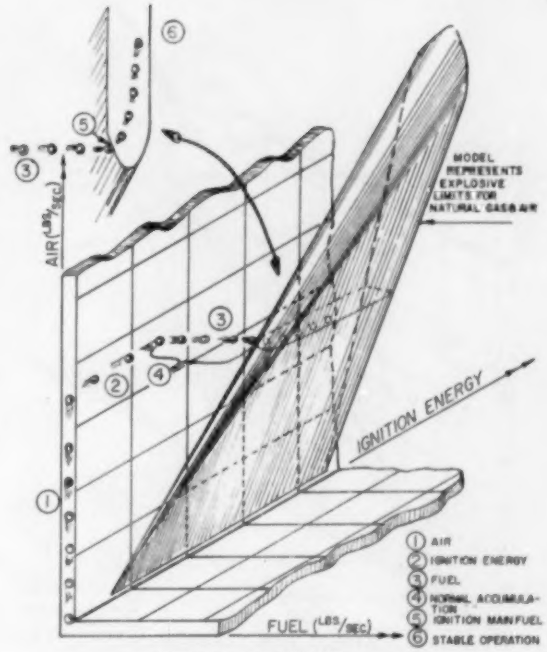
The furnace conditions necessary to have a "puff" (very high heat release rate) are similar to those required for most commercial combustion reactions. Normally, burners supply the reactants, usually fuel and air, only as fast as they are consumed. The opportunity for contact between the reactants is controlled, and continuous adequate ignition energy is supplied to the mixture.

Furnace explosions result from the ignition of unburned fuel and oxygen *after* they have accumulated in a unit. The reactants, however, must be present in certain ratios before combustion can occur. These

* Presented before the 3rd National ISA Power Instrumentation Symposium, May 9-11, San Francisco, Cal. sponsored by the Instrument Society of America.

† Project Engineer, Fuel Equipment, Chattanooga, Tenn.

[1] Numbers in parentheses refer to similarly numbered items in References at the close of the article.



PROPER OPERATION

Fig. 2—The step-by-step procedure for properly establishing combustion within a furnace is given by the numbers. Follow the numbered dots:

(1) Air is admitted and you travel up the ordinate of the graph to where the dots turn off . . .

(2) as initial ignition energy is turned on. Then the dots move at right angles . . .

(3) along the abscissa of the graph to indicate that main fuel is admitted . . .

(4) shows the normal buildup of fuel to air ratio under adequate auxiliary ignition conditions to establish main flame operation. Then we refer to the horizontal plane shown at the opposite end of the arrow in the upper left part of the illustration . . .

(5) is where the main fuel has become ignited and . . .

(6) where stable burner operation has developed

fuel-air ratio explosive limits range from 4.8 to 13.5 per cent by volume of natural gas (1000 btu/ft^3) in air (3), to 0.2 to 2.0 oz of 200-mesh bituminous-coal dust per cu ft of air (1). There are four general operating conditions which can provide these accumulations. Specific examples of each are discussed later.

1. Inadequate or improper sequencing of initial and subsequent ignition.
2. Interruption and recurrence of combustion reactant mixtures.
3. Fuel delivered to the combustion chamber improperly prepared to ignite and burn with the given burner-furnace design.
4. Fuel and air delivered to the furnace in noncombustible ratios or improperly combined to promote the desired ignition and firing pattern.

A satisfactory description of the circumstances which can cause explosive furnace conditions should begin by generally describing present furnace firing techniques.

Current Methods of Commercial Furnace Firing

Almost all furnaces are fired by devices (burner nozzles or burners—see Fig. 1) which are supplied with separated quantities of fuel and air. The burners function to instigate and direct a specific pattern of mixing between the reactants within the furnace. These devices are seldom designed to completely premix the fuel and air before they enter the combustion chamber and normally supply the reactants partially combined in a manner compatible with the furnace design. In a properly designed and operated unit, combustion should begin near the burner and be continuous to the main flame envelope. Thus, combustible fuel-air mixtures seldom exist in appreciable quantities in normal furnace firing.

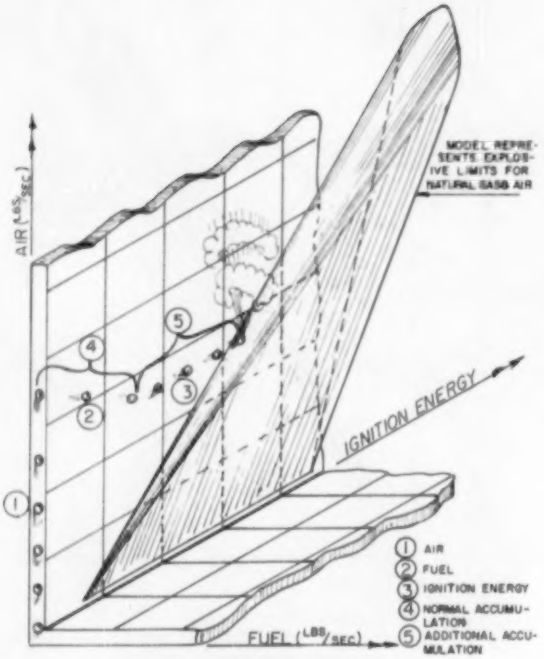
Safe furnace firing is usually obtained by step ignition. An electric spark is normally used to start the ignitor which, in turn, is used to start the large oil or gas guns. These ignition energies are used, in turn, to ignite and stabilize main burner operation. Above certain limits main burner firing is designed to provide sufficient self-ignition energy so that auxiliary ignition is not required.

Ignition systems are usually designed to provide safe burner light off and stabilization by igniting the fuel-air product as close as practicable to the burner before extensive mixing can occur in the furnace. The ignited burner products are normally directed to provide a firing and flow pattern which promotes inherent flame stability. The usual stabilizing technique employs part recirculation of combustion products back to the unburned reactants coming from the burner. In most furnaces there is significant heat transfer back to the unburned reactants by radiation from the flame envelope.

Operating Conditions Causing Furnace Explosions

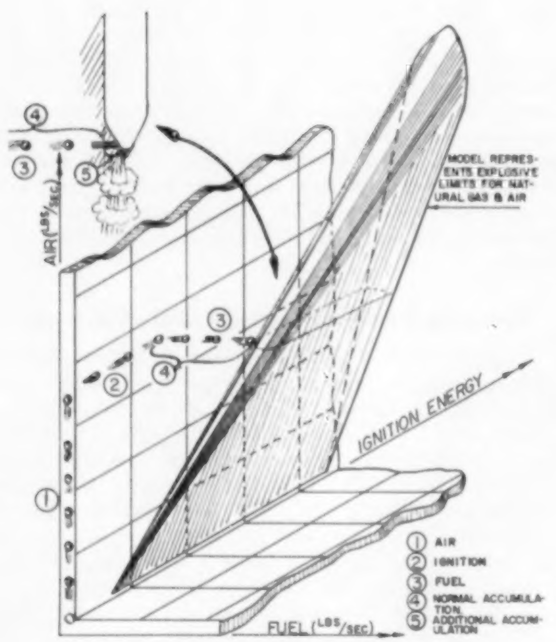
Furnace "puffs" result from supplying the furnace with fuel, air and ignition energy in improper sequence, pattern or condition. Figure 2 shows, qualitatively, the required relationships of the three ingredients essential for combustion. Various furnace operation techniques can be readily understood by tracing the furnace conditions of this graph. The following examples of operation, which may cause an explosion of a unit with properly performing main burners using satisfactorily prepared fuels, are illustrated on similar graphs.

1. Start with any dark furnace. Turn on the main fuel and air without providing auxiliary ignition. Then, after the flows are established, provide suitable ignition. Figure 3 shows this process (improper operating sequence).
2. Start with any dark furnace. Provide auxiliary



IMPROPER OPERATING SEQUENCE

Fig. 3.—In this graph the sequence from Fig. 2 has been changed. Air and fuel have been provided before supplying auxiliary ignition (3). The optimum fuel air ratio accumulation (4) is exceeded and more time (5) goes by before the mixture ignites. When it does it produces a furnace puff



INADEQUATE INITIAL IGNITION

Fig. 4—An inadequate initial ignition energy is provided in this instance. Fuel-air ratio reaches explosive mixture short of the possible ignition point and when ignition occurs—puff results

ignition incapable of igniting the partially mixed main fuel-air flow as it comes from the burner device. Wait. If the auxiliary ignition is sufficient to ignite a more intimate fuel-air mixture, a "puff" will result.

With no main fire to consume the reactants, the burner products will mix in the furnace and eventually reach the igniting device with an explosive combination. Figure 4 illustrates how this occurs (inadequate initial ignition).

3. Start with any properly operating furnace with the auxiliary ignition devices out of service or operating as in 2. Turn the fuel off—or reduce the flow below the minimum inflammability limit. After a short time, turn the fuel back on. This furnace reactant accumulation can be ignited, in a hot furnace, even if the auxiliary ignition is off. There are many possible ways of obtaining the ignition energy required and slag deposits make excellent ignitors. After the described fire goes out, hot slag may ignite the accumulated and mixed reactants, even after a considerable period of time. Figure 5 shows the usual furnace operating sequence which causes this "puff" condition (interruption and recurrence of furnace fuel supply).

4. Start with any properly operating furnace with the auxiliary ignition devices operating as in 2, or out of service. Turn the air off or reduce the flow until the mixture is too rich to burn. After a short time turn the air back on. Ignition of the accumulations can occur as in 3. Figure 6 shows this situation (interruption and recurrence of furnace air supply).

5. Start with any properly operating furnace with the auxiliary ignition system off or on and operating as in 2. Reduce the air/fuel ratio until the fire goes out. With the air still on, cut off the fuel. This will supply a non-combustible fuel-rich furnace atmosphere with the air it needs for a puff. Ignition of the mixture can occur through either of the methods described in 2 or 3. Figure 7 illustrates the operation which can produce this puff (interruption and recurrence of combustible reactant mixtures). Note that, in this case, a "fail safe" fuel trip can *cause*, rather than prevent, an explosion by providing the accumulated fuel-rich furnace mixture with the air it needs to become explosive.

6. Start with any dark furnace. Allow the fuel to leak into the combustion chamber until it is well filled. Partially air purge the furnace. Turn on the auxiliary ignition system and fire up normally. Most furnaces have large eddy zones which can retain substantial reactant accumulations through many furnace air "changes." A normal startup can provide the mixing and the ignition energy required for these reactant supplies to explode. Figure 3 also describes this case.

Furnace "puffs" can be caused, regardless of operating technique, by burners which are not providing the combustion chamber with properly mixed or directed reactants.

1. The burner product may be such that the auxiliary and/or inherent ignition systems cannot insure safe firing. If the reactant flows are igniting too far from the burner, accumulations can occur and be intimately mixed by the burner flow energy before sufficient ignition energy is supplied. The result may be a puff.

2. Combustible fuel and air furnace accumulations can also be provided if the delivery fuel supply is improperly prepared. Poorly atomized fuel oil, low tem-

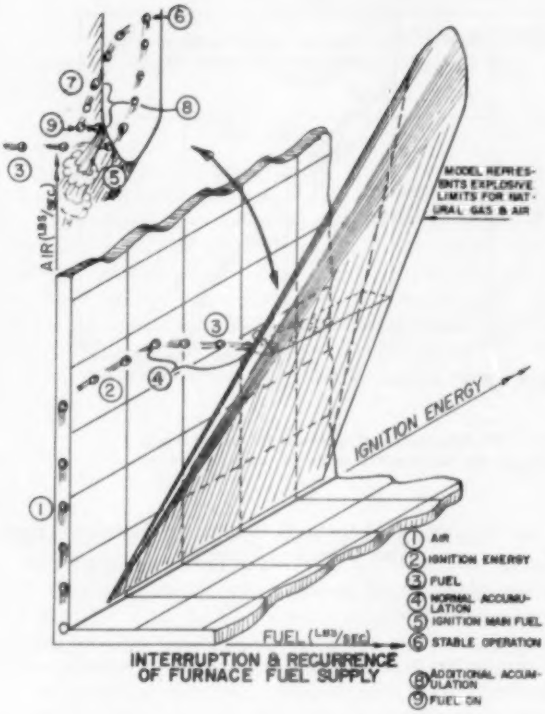


Fig. 5—Up to point (6) this graph duplicates Fig. 2. But then the fuel supply is shut off at (6) and turned back on for a while (8) the hot furnace succeeds in lighting off the mixture (9) with an explosive puff without auxiliary ignition

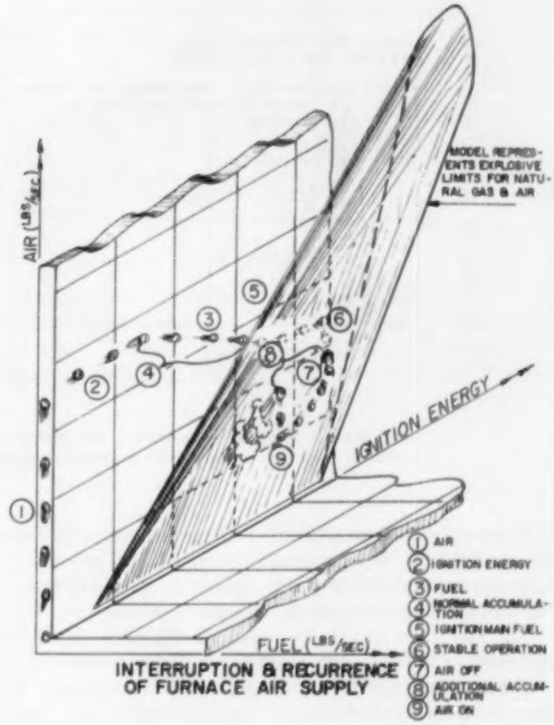


Fig. 6—This situation follows Fig. 2 to point (6) and then the air is shut off as was the fuel in Fig. 5. The same "puff" condition develops when the air is turned on again

perature and/or extremely coarse pulverized coal (1), etc. can be too difficult to ignite with the maximum ignition energies available. If the furnace reactant accumulations then become ignitable, as a result of being sufficiently heated and/or mixed in the furnace, for example, an explosion may occur.

Present Methods Used to Prevent Furnace Explosions and Their Shortcomings

A reliable system of preventing furnace explosions must provide means to avoid each and all of the situations which can cause an explosion. There are many commercial devices and/or systems, presently available, which are applied as a system to prevent furnace explosions—but which are incapable of preventing all, or even part, of the puff situations outlined. These systems are usually designed around one or more flame detecting devices interlocked with the fuel supply valves. These systems claim to "fail safe" by shutting off the fuel flow for any reason that the flame detector shows the fire is out and/or because the detector itself malfunctions.

A flame detector device cannot prevent furnace explosions by itself. A reliable flame indicator is needed as part of an integrated system of devices which can prevent the occurrence of all the situations required for an explosion.

Although the current "flame safeguard" systems may be well equipped with other devices which insure a preferred starting sequence, they frequently have unrealistic times for purging and "trial-for-ignition" features which

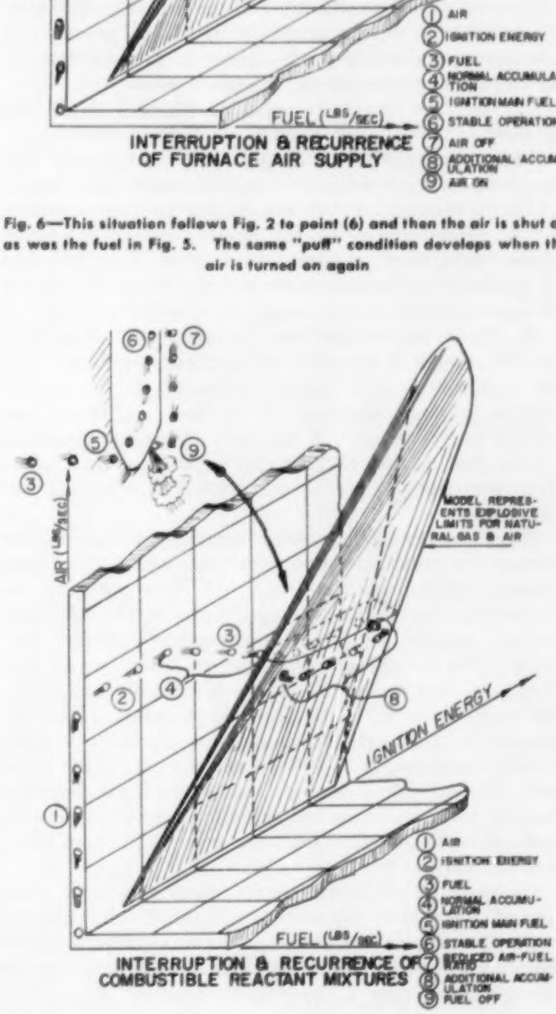


Fig. 7—In the above graph the air-fuel ratio is reduced to where the flame goes out (7). The fuel supply is cut off but the air flow still continues (so-called "fail-safe" condition) (8) to where the non-combustible fuel-right furnace atmosphere reduced in fuel content enough (9) to cause an explosive puff

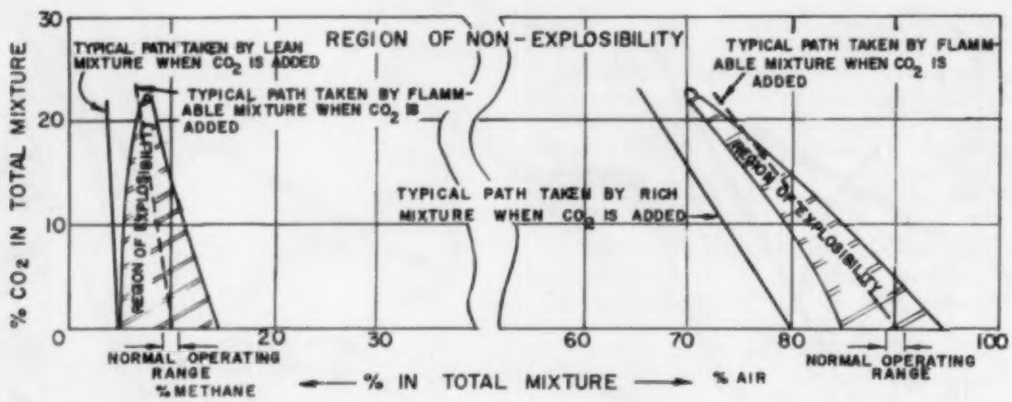


Fig. 8—As a means of establishing a safe shutdown system it has been proposed to replace burner air supply with an inert gas. Above chart depicts the effect of CO_2 on the flammability limits of methane and air

can impede good operation. Indiscriminate stoppage of the fuel flow is not an infallible method of providing a safe furnace shutdown. In general, present furnace "protecting" systems have two basic deficiencies:

1. They are unable to establish whether or not the ignition systems (self and/or auxiliary) are actually capable of properly igniting and/or stabilizing any burner operating condition. Or, conversely, they cannot establish whether or not the burner product supplied can be safely ignited by the ignition energy available. These "safeguard" systems often allow main fuel and air flow, even though the reactants may accumulate in the furnace unignited, simply because the ignitor is "on."

2. They are unable to determine, or determine quickly enough, if the main fire goes out, whether it was due to a rich or lean furnace mixture. If the air-fuel ratio is too high, shutting off the fuel is a flawless explosion preventative. If the ratio is too low, shutting off the fuel may even cause an explosion. In essence then, present systems cannot always shutdown a furnace safely.

Many burner-furnace firing systems utilize multiple burners for only one flame envelope—usually for many reasons other than simplicity. If these furnaces are "protected" by a system using a flame detector for each burner, unsafe firing and unwarranted outage may result. An individual flame scanner on a burner may "fail safe" and put out the entire fire merely because the fire went out in its particular field of vision. This can happen even though the main flame envelope is functioning satisfactorily. If the flame detector shuts down only the individual burner, the whole flame envelope may be unbalanced by the rapid change in fuel and air flows going to the other burners—and a hazardous situation is created.

On units which have multiple flame envelopes, shutting off the fuel to one burner will usually decrease the air/fuel ratio going to the other burners. The resultant supply upset to the remaining flame envelopes, if severe enough, may cause a complete furnace outage.

Basic Requirements for a Complete System to Prevent Furnace Explosions

An effective, practical flame safeguard system must contain four main features:

1. An auxiliary ignition system which can reliably ignite and stabilize any main burner product over a range of operating conditions considerably greater than those anticipated.

This auxiliary ignition equipment is not simply provided. Much work needs to be done to establish what amount, form and location of ignition energy is optimum for reliable ignition and stability of various burner products.

The ultimate in an ignition and burner system design would eliminate explosions by always properly consuming furnace reactant supplies—thus preventing their accumulation. Such a system, if sufficiently reliable, would only have to be interlocked to operate in the proper sequence, as per Fig. 2, to provide safe firing.

2. A reliable "fail safe" flame detector set-up for the auxiliary ignition system which can indicate the amount of ignition energy available.

The flame monitor can then be used with the appropriate devices to insure safe ignition and/or stabilization of the main burner product.

Combining items 1 and 2 with proper furnace start-up and operating sequences will insure safe main burner ignition and stable burner operation—when the auxiliary ignition system is in service.

3. A reliable "fail safe" flame detector system for each main furnace flame envelope which can detect the total ignition energy available.

The detector output can be correlated with the burner fuel and air flows to insure that enough oxygen and fuel will react to supply the required self-ignition energy. The system might be used to correct unsatisfactory firing conditions before loss of ignition occurs.

The flame detector should be interlocked into the other control subloop interlocks so that, as long as the main flame envelope is functioning satisfactorily, the main burner supplies will continue to flow.

4. A system which can, under any condition, safely shut down a furnace. A safe shutdown system should be developed for all automatic or manually operated units.

Such a system might include, for example, a device which could replace the burner air supply with a supply of relatively cool inert gas—before the burner fuel supply was tripped. Figure 8 shows the effect of inert gases on the inflammability limit for methane and various

shutdown sequences. Putting the inert gas through the burners would help prevent additional air flow to the furnace.

Conclusions

The proper relationship of the flame detector to an integrated system for preventing furnace explosions has been discussed. Avoiding the situations which are necessary for a puff will require the development of reliable subsystems to ignite, stabilize, indicate, and safely shutdown main burner operation. Although these requirements for true furnace protection may seem strict, they must be satisfied before a reliable system for preventing explosion can become a reality.

REFERENCES

(1) Hartmann, Irving; Jacobson, Murray; and Williams, R. P.—"Laboratory Explosibility Study of American Coals," Bureau of Mines Report of Investigations 5052—United States Department of the Interior—April 1954.

(2) "Standard of the National Board of Fire Underwriters for the Installation and Operation of Pulverized-Fuel Systems," National Board of Fire Underwriters, July 1957.

(3) "Hauck Industrial Combustion Data," Hauck Manufacturing Company, 1953.

Acknowledgment

The information presented in this paper resulted from the cooperative efforts of Mr. V. Z. Caracristi and Mr. J. Jonakin. Messrs. J. J. Payne and W. D. Dykes provided considerable assistance in preparing the Figures.

Appendix I

The Differential Pressure Method of Indicating Furnace Firing Conditions

The present economics of steam generation increase the industry's demand for large, single, flexible steam generating units which provide a reduced personnel/mw requirement. This magnifies the need for a dependable system to prevent furnace explosions and protect this concentrated investment. Furnace explosions are not only dangerous, but are very expensive. The high price of field repair and the increasing costs of lengthy big boiler outages are significant. Present flame safeguard systems, although well equipped with flame detectors which are designed to "fail safe," are not adequate to guarantee safe furnace operation. A practical furnace protecting system, which is capable of properly controlling furnace supplies to provide maximum availability while preventing furnace conditions necessary for an explosion, will be the result of properly interlocking many devices and their subsystems.

Although a satisfactory flame indicator is an essential and basic component for the practical furnace safeguarding system, detectors must be considered as only part of, and in proper perspective to, the total furnace protecting scheme.

If every furnace control system were continuously monitored by a competent unit operator, there would be little need for a flame indicator. There are many measurements, such as changes in furnace draft and drum

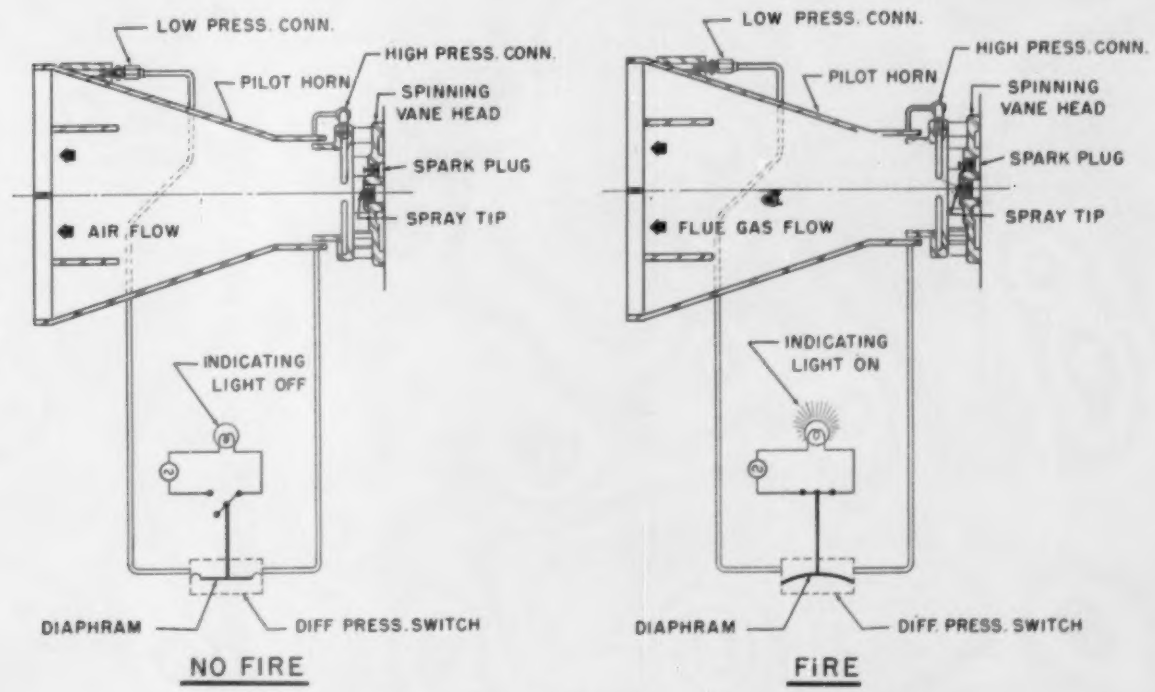


Fig. 9—Fig. 9(a) shows the application of the differential pressure method of flame proving to a side igniter with no flame. Fig. 9(b) shows the system with flame established

water level, which can provide an alert operator a description of the fires. In the present state of the flame detector art, however, there are no commercial devices which can completely and reliably describe furnace firing conditions. Furthermore, even if there were a satisfactory flame detector device, it has not yet been established how to properly integrate the detector responses with the boiler control and interlock systems to avoid all possible furnace puff conditions.

With a realistic relationship of the flame detector to a furnace protecting system now established, the C.E. ΔP methods of flame detection will be discussed.

Basically, the ΔP method of indicating furnace firing conditions consists of measuring the furnace pressures at two or more key points in a combustion chamber and then properly interpreting differential pressure changes, with changing firing conditions, through indicating and switching devices.

One method of applying this basic concept has been developed for commercial use on the C.E. side ignitors (Fig. 9), with over a thousand presently in service. The ΔP technique used for flame indication on this device, which operates at heat release rates over 2 million Btu/hr/cf., employes the change in static pressure drop across the horizontal ignitor combustion chamber between no-fire and firing conditions. The taps were designed to provide the characteristic curves shown on Fig. 10 and to permit the use of a simple ΔP switch. Note that the ΔP changes are a function of the heat release rate (related to the ignitor air flows). This quantitive ignitor firing information is utilized to insure that the ignitor is on *and operating* properly before the flame indicator switch is actuated, showing the fire has started. This desirable feature is incorporated by adjusting the ΔP switch set point as shown on Fig. 10.

Experimental test results show that this method of pressure interpretation is probably limited to combustion chambers operating at heat release rates over 0.1 million Btu/hr/cf.

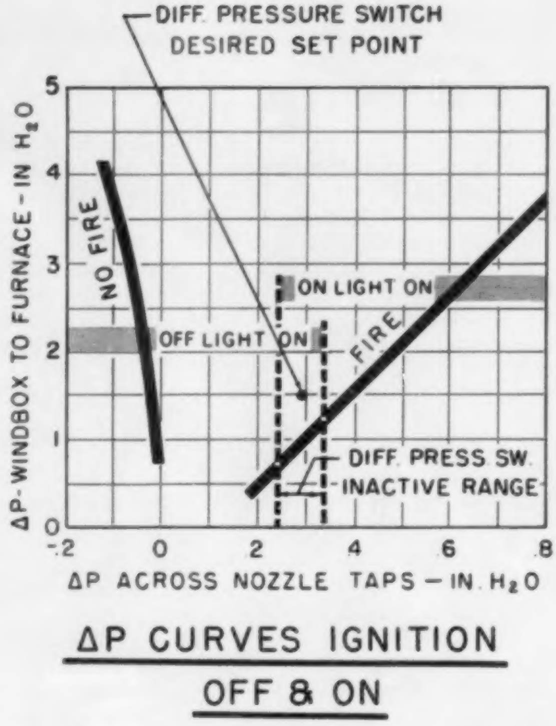


Fig. 10—Characteristic curves of differential pressure values obtained across ignitor

A different approach to utilizing furnace ΔP change phenomena for indicating unit firing conditions is presently being developed for use on large vertical furnaces which heat release rates well below 0.1 million Btu/cf/hr.

This technique utilizes the change in combustion chamber static pressures between various fire and no-fire conditions provided by the stack effect. The stack

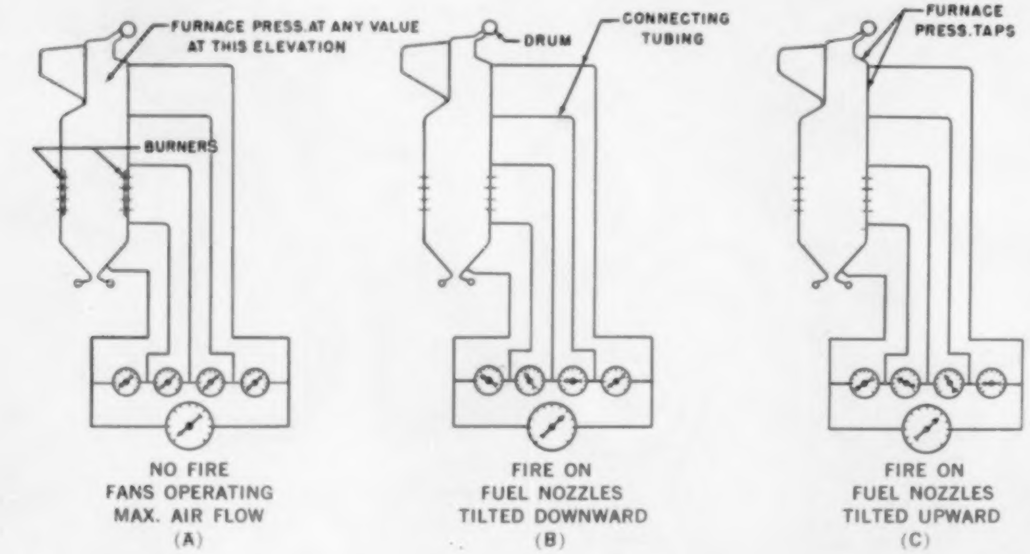


Fig. 11—Schematic arrangement of tangential firing system with Δ P furnace protection. (a) no fire, (b) fire on, fuel nozzles tilted down, (c) fire on, nozzles up. This furnace is 100 ft high

effect over a fixed height in a furnace is, for all practical purposes, a function only of the furnace gas density. This density, in turn, is a function primarily of the heat release rate—the result being that these ΔP measurements can also be correlated to indicate, through the appropriate devices, furnace heat release rates.

Both ΔP flame indicating methods, furthermore, can be applied to tell not only whether or not the fire is on and how much fire is present, but where the fire is. Figure 11 shows, schematically, a unit with C.E. tilting tangential burners using this system. Note how the pressures shift as the fire shifts—but that the ΔP across the furnace shows no change for the same heat release rate.

The advantage of the stack effect ΔP system is that furnace flow conditions and tap configurations have inconsequential influence on the ΔP. Neither ΔP flame detecting technique is affected by changes in absolute combustion chamber pressures.

The ΔP system time responses after a fire change are less than $^1/_2$ sec. The simplicity of the ΔP systems will aid in a continuing effort to obtain good flame detector reliability.

Seven different units, operating with various fuels, are presently equipped with ΔP systems or are being adapted for them. In order to utilize simple ΔP indicating the switching devices, it is necessary to compensate for the stack effect of the hot gas in the furnace when the fires are out and the furnace temperatures are above atmospheric. This can be done by several methods now under test. These field installations use two methods, and one set-up has controlled temperature compensation of the ΔP switch. Correcting the expected bugs and obtaining long term operating data are present goals which will establish if and how the ΔP stack effect system can be best commercially applied for reliable furnace flame indication.

Combustion Symposium Program Excerpts

The week of Aug. 29 through Sept. 2 saw the Eighth Symposium (International) on Combustion at the California Institute of Technology, Pasadena, Calif. Some 133 papers from 233 contributors representing 16 countries were to be given and all will be published in the proceedings available at a charge from the Combustion Institute, Union Trust Building, Pittsburgh 19, Pa., Mrs. Helen G. Barnes, executive secretary.

Most of the papers offered dealt with theory and experiment related to propulsion development and high-speed flight but a number of the papers did deal with basic problems of combustion research, laminar and turbulent flames, ions in flames and chemical kinetics. We list some of these sessions as a guide to the nature of the subjects covered:

SESSION I—INVITED SURVEY PAPERS

Chairman: B. Lewis

Monday, Aug. 29 — 10:00 A.M.–12:30 P.M.

I-1. H. Eyring, Dean of the Graduate School, University of Utah, "Mechanism of Ion Formation in High-Temperature Flames"

I-2. M. Biondi, Westinghouse Research Laboratory, Pittsburgh, Pa, "Collision Cross Sections Involving Ions and Electrons"

I-3. J. A. Fay, Associate Professor of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass., "Detonations"

I-4. L. Lees, Professor of Aeronautical Engineering, California Institute of Technology, "Boundary Layer Phenomena with Combustion"

SESSION IIA—IONS IN FLAMES

Chairman: F. J. Weinberg

Monday, Aug. 29 — 1:30–5:00 P.M.

1. "Identity of the Most Abundant Ions in Some Flames," S. De Jaegere, J. Deckers and A. van Tiggelen
2. "An Experimental Determination of the Electron Affinities of the Lower Alkyl Radicals," F. M. Page
3. "Some Observations on the Production and Recombination of Ions and Electrons from Metallic Additives in Hydrogen and Hydrocarbon Flames," P. J. Padley and T. M. Sugden
4. "Further Studies on the Decay of Free Electrons in the Mantle of an Acetylene-Air Flame," H. Williams
5. "Ion Production and Recombination in Flames," H. E. Calcote
6. "Flame Ionization During the Development of Detonation," A. J. Laderman, R. A. Stern, G. J. Hecht and A. K. Oppenheim

SESSION IIIA—IONS IN FLAMES

Chairman: J. B. Fenn

Tuesday, Aug. 30 — 9:00 A.M.–12:00 Noon

15. "Measurements on Field-Induced Ion Flows from Plane Flames," K. G. Payne and F. J. Weinberg
16. "Photographic Recording of Slow Ions from Flames," F. J. Ward and F. J. Weinberg
17. "Mechanism of Ion Formation in High Temperature Flames," Henry Eyring, Nalin R. Mukherjee, Takayuki Fueno and Taikyue Ree
18. "Catalytic Dissociative Reactions in Electrical Discharges," Frederick Kaufman and John R. Kelso
19. "Ionization in Rocket Flames," H. G. Wolfhard, J. Nichol and V. Siminski
20. "Direct Generation of Power from a Combustion Gas Stream," S. Way and R. L. Hundstad

SESSION IVA—CHEMICAL KINETICS

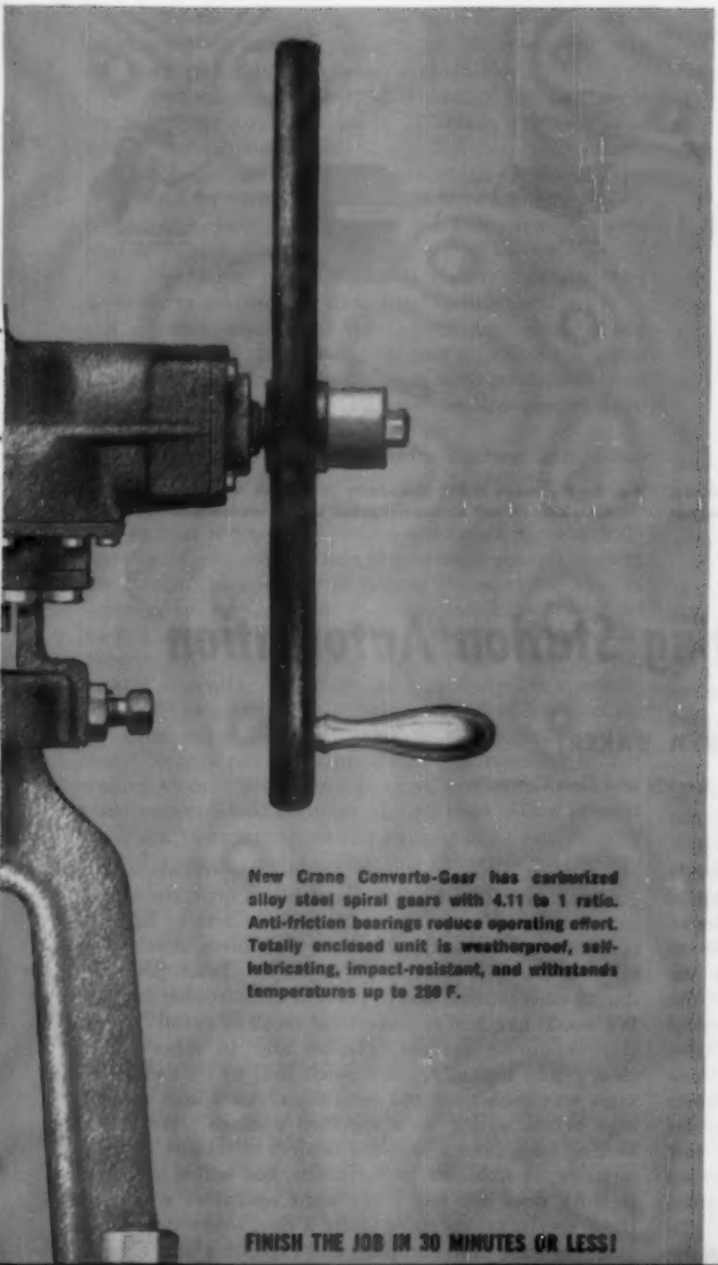
Chairman: W. Jost

Tuesday, Aug. 30 — 2:15–5:15 P.M.

29. "A New Method of Examining the Reactions of Oxygen Atoms," B. G. Reuben, J. W. Linnett and M. Barber
30. The Dissociation of Hydrogen Peroxide and its Role in the Hydrogen-Oxygen Reaction," R. R. Baldwin, P. Doran and L. Mayor
31. "The Homogeneous Gas Phase Decomposition of Hydrogen Peroxide," R. R. Baldwin and D. Brattan
32. "Thermal Mechanisms Related to the Photolysis of Nitrogen Dioxide," Hadley Ford
33. "Rate of the Reaction $O + N_2O \rightarrow NO$," C. P. Fenimore and G. W. Jones
34. "High Temperature Gas Kinetics Using the Logarithmic Photometer," F. Kaufman and L. J. Decker

OTHER SESSIONS

Space does not permit listing of all sessions but Session VIC—Formation and Combustion of Solids, Session VIIC—Complex Combustion Processes and Session IXA—Turbulent Flames all appear worthy of attention.



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WHY OVERALL CONTROL SHOULD BE INTEGRATED

1. UNIT OPERATION IS COMPLEX
2. PRE—PLANNED OPERATION IS ALWAYS FOLLOWED
3. CORRECT DECISIONS MUST BE MADE RAPIDLY
4. FUEL COSTS CAN BE MINIMIZED
5. OUTAGE TIME CAN BE REDUCED
6. FEWER PERSONNEL WILL BE REQUIRED

Fig. 1—A computer type control system possessing these characteristics should, in the author's opinion, be the preferred next step in automation

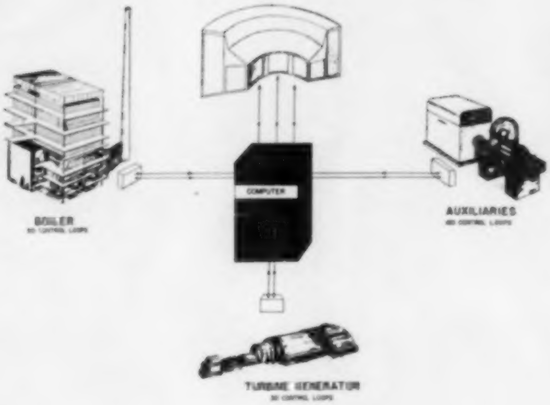

Fig. 2—The above sketch graphically shows the role proposed for the computer. It will be superimposed on the conventional system

*A Look At Generating Station Automation**

By R. A. BAKER†

Public Service Electric and Gas Company

ADVANCES in the art of generating station design have developed in partnership with advances in the art of instrumented control. The super power station of thirty years ago had four separate control locations—one for the boilers, another for the turbines, still another for the major auxiliaries, and the remaining location for electrical control. These control areas were remote from each other and required telephone, loudspeaker, and servo indicators for the flow of information from operator to operator. The efforts of one man were required to operate each 15 megawatts of installed capacity. Fifteen years later, and just fifteen years ago, control systems had been conceived to perform automatically many of the routine functions and to initiate operation from a central point. The central control room was being born. Incidentally, the need for operating personnel was reduced to one man for each 30 megawatts. That idea of centralizing our controls has been expanded in scope, improved in technique, and physically miniaturized. Today, there are approximately 100 megawatts installed per operating position—a dramatic six-fold reduction in personnel requirements for new plants that are exceedingly more complex.

This revolution has been won by the technology of control. We stand at the point where all significant areas to be controlled have reliable, self-contained analog systems. Examples such as feedwater flow and voltage regulation require the operator to set a basic control point from time to time. Overall coordination and guidance is left to his judgment based on training and experience. We optimistically look to him to find the combination of settings which minimizes costs. We rely on his wits to avert danger, to direct activities during emergencies, and to prevent catastrophic damage. We would like him to have total recall of detail circumstances during certain episodes and to report them clearly and logically. We teach him to do things the same way each time and carefully check a host of readings before acting in a specified manner. We're still looking for a man who is not subject to fatigue, lapse of memory, or unbiased performance, and whose attention to duty does not flag. We want operators who meet these specifications three shifts a day, every day of the year, for each new, complex, and expensive unit that we build.

These specifications are superhuman and suggest the answer that a superhuman operator be given a trial. We envision a digital control computer as being capable of operating a unit. Accordingly, the Public Service Electric & Gas Company formed a task force consisting of engineers from various departments to study the application of computers to power plants. Initial results of this study have been encouraging because it is readily apparent that automation offers the opportunity for significant advances in both design and operation.

As a result of our study during the past few months, we picture a type of computer control which has the characteristics shown in Fig. 1. These are as follows:

1. Automatic start-up without manual operation of any kind after the generators have been filled with

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† Chief Engineer, Electrical Engineering Dept.

hydrogen, the boiler circuit has been filled with water, lubricating oil has been placed in all reservoirs, and auxiliary power has been made available.

2. Optimum operation by trimming the set points on automatic control circuits to obtain the best heat rate under all conditions.

3. Routine and full scale equipment efficiency tests performed by means of the computer's inherent ability to measure quantities and convert these readings into heat rates and other measurements of efficiency.

4. Operating records prepared daily, weekly, and monthly in addition to data logging functions.

5. Better equipment protection by continuously monitoring operation, detecting and alarming abnormal and unsafe conditions, correcting such conditions, and taking the necessary steps to prevent equipment damage.

6. Automatic shutdown under routine and emergency conditions in a safe and orderly manner.

7. Independent instrumentation for manual operation so that a computer failure will result in an orderly transfer of control to the conventional control system and inform the operator of system status at the time of failure. In our present stations, we have some 50 control circuits associated with the boiler, some 30 circuits with the turbine-generator, and roughly 100 control circuits installed on auxiliary equipment. Some of these loops are self-contained and have no supervision other than an alarm in the central control room; others can be adjusted by the operator in the control room. We do not propose to eliminate any of these conventional controls at this time. Our present plans are to superimpose the computer on our existing control system, maintaining the conventional system so that control can be transferred quickly from the computer to the conventional system when necessary. This is shown pictorially in Fig. 2. The computer is, therefore, not an entirely new control system, but merely an aid to safer and more efficient operation of an established system.

There are a number of reasons why we believe control systems should be integrated by a control computer, as listed in Fig. 3.

1. Unit operation is complex. Along with the increase in size of turbine-generator units and the development of new steam power plant designs for greater operating efficiency has come an increasing complexity. It is not humanly possible for one man to understand the intricate details of all phases of generating station operation. The computer is superhuman and has a capability for rapid accumulation and retention of facts far beyond the capability of any single human brain.

2. Preplanned operation is always followed. Computer programming permits immediate response to all operating conditions in a safe and orderly manner. It will respond consistently to the same set of conditions in the desired way. The problem of programming a computer to foresee all possible conditions under which a unit may be forced to operate is a difficult one, but once the programming is established, the computer will perform its task with an infallibility which no operator possesses.

3. Correct decisions must be made rapidly. Because of the tremendous capital investment in a turbine-generator unit, it is essential that operating decisions be

CHARACTERISTICS OF PROPOSED INSTALLATION

1. AUTOMATIC START—UP
2. OPTIMUM OPERATION
3. PERFORMS EQUIPMENT EFFICIENCY TESTS
4. PREPARES OPERATING RECORDS
5. PROVIDES BETTER EQUIPMENT PROTECTION
6. AUTOMATIC SHUT—DOWN
7. INDEPENDENT INSTRUMENTATION FOR MANUAL OPERATION

Fig. 3—The author states his case for integrating the overall control system with a computer control

correct and that they be as rapid as possible. A computer, because of its inherent high speed of response and preplanned courses of action, has the ability to make correct decisions virtually instantaneously.

4. Outage time can be reduced. By more rapid detection of equipment malfunctions and by taking the unit out of service rapidly and safely when a failure does occur, the computer will reduce unit outage time. By programmed start-ups and shutdowns which will be established on minimum time requirements, additional outage time will be saved.

5. Fuel costs can be minimized. To investigate this area, we instituted a testing program to determine potential fuel savings, how they can be obtained, and the control technique required. We performed continuous input-output measurements with the data collection equipment shown in Fig. 4. Here, the outputs from strain gage and flow transducers were fed into the voltage-to-frequency converters shown beneath the magnetic tape recorders. The magnetic tape units record these quantities along with timing pulses. Additional recording units, shown on the left above the amplifiers, recorded fuel oil and generator quantities. A tape-to-punched card converter prepared all data for calculation on an IBM 650 computer. The results from a typical series of runs, all at substantially constant load, may be seen in Fig. 5. We found relatively flat frequency distribution around the mean value which suggests to us that a control system incorporating automatic set point adjustment would obtain a mean heat rate equal to that which we could obtain by manual set point adjustment only 20 per cent of the time. This improvement amounts to at least 1 per cent through automatic set point adjustment. Results from our tests to determine additional improvement due to selective set point adjustment toward optimum cycle efficiency are still preliminary, but they appear to offer at least as much, or more, additional savings. We feel that the continuous and consistent functioning of the computer can attain these savings.

6. Fewer personnel will be required. There will be a decrease in the amount of operator attention required because of the complete coverage of all phases of equipment operation by the computer, and this will result in a reduction of operating personnel. Because of the performance testing capability of the computer, there will be a decrease in the personnel required for tests. Because of the ability of the equipment to prepare re-

ports and compute period performance, there will be a reduction in performance department and clerical personnel.

We believe a digital computer is the best choice for power plant automation because the digital computer has significant advantages over other devices in terms of reliability, accuracy, flexibility, simplicity, and cost.

The foremost advantage is reliability. By using relatively few components to perform all these functions, it becomes feasible to use the best grade available. The digital computer operates by counting electrical pulses and it doesn't matter whether the pulse is large or small. Component change over wide limits may alter the size of a pulse but, as long as the pulse can be recognized, it will be counted and will not affect accuracy or operation.

Accuracy is limited only by the sensing elements. The computer's ability to apply complex correction factors to inputs will make accuracy of sensors less important than their repeatability. It is believed that an overall accuracy of better than two-tenths of 1 per cent can be obtained.

The operations of the digital computer are controlled by the program stored in its memory. The same hardware is used, regardless of the program. A general view of the total equipment involved can be seen in Fig. 6. Changing a program requires only typing the correction, which the computer then puts into its memory to replace the section of program to be changed. For example, the original boiler start program may call for increasing the main steam temperature by 300 deg per hour. If, during operation, it tu ns out that this should be only 250 deg per hour, the program could be changed in less than a minute.

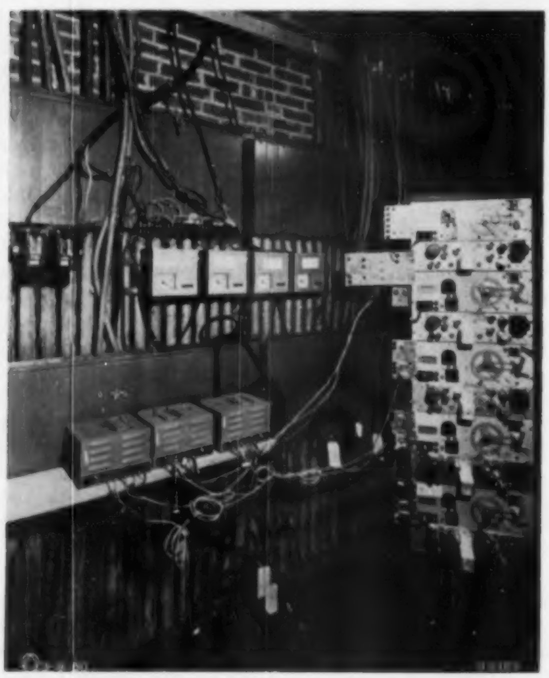


Fig. 4—Public Service decided to investigate possible fuel savings, their methods of determination and the type of controls to effect them. Continuous input-output measurements with above collection equipment were run

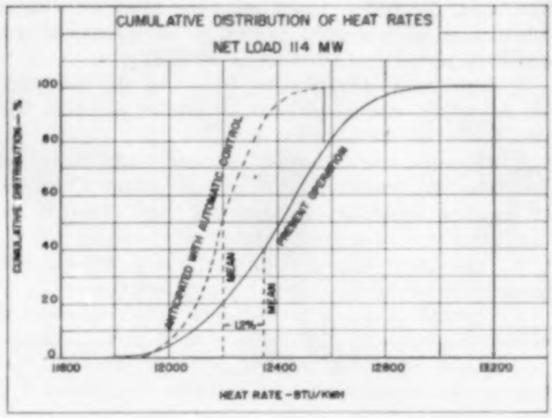


Fig. 5—Cost results from Fig. 4 tests produced above solid line curve. The manual set point adjustment now used as contrasted with an automatic set rate would achieve the same economies only 20 per cent of the time

The digital computer uses the same circuits to accomplish hundreds of different operations. About half of the computer circuits are the same, and there are only about 20 different types of circuits in all. One of our stations has a data logger, which may be thought of as a little brother to a control computer, which has operated reliably over 99 per cent of the time. During a recent strike of operators, when the station was manned for 39 days solely by supervisors, a failure occurred, and the station supervisors described the symptoms to the manufacturer who, in turn, gave instructions on how to repair it, all by telephone.

As mentioned earlier, the digital computer uses relatively few circuits to perform all its operations. This, in turn, makes the digital computer the least costly of the control devices. To properly evaluate a control computer, we must examine the capital cost of the project and then consider this cost in the light of capitalized savings.

For the 342-mw unit under study, we estimate a total installed cost of $850,000, which is judged to be a reasonable percentage of the total estimated instrumentation and control costs for a unit of this size. Fig. 7 itemizes our cost estimates.

The computer and the associated sensing devices, tubing, conduit, wiring, switches, and relays necessary to integrate the computer with the conventional control system are estimated to cost $560,000. We estimate that the computer can be installed for $25,000, and $100,000 has been allowed for the installation of associated equipment. The engineering and design estimate of $75,000 represents more than 75 man-months for the very specialized engineering and design work involved. Overheads of $45,000 and a contingency of the same amount give us the total of $850,000. However, the computer eliminates the need for a data logger and automatic load dispatching equipment, which are integral with the computer. These yield a saving of $95,000, as they are already included in the scope of the overall unit estimate, so that only $755,000 of additional funds are required for the complete computer system.

We have itemized estimated savings in Fig. 8. In arriving at these figures, we have tended to be conservative.

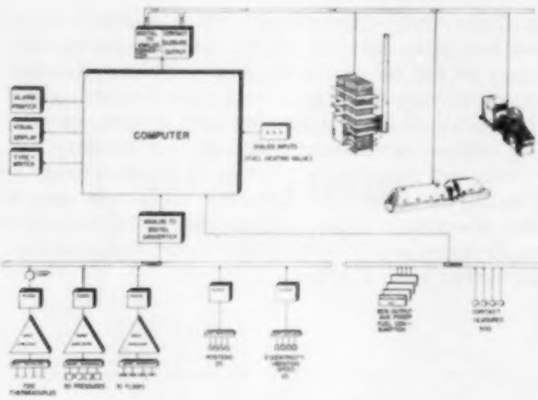


Fig. 6—A somewhat schematic view of the total equipment used for a digital computer program such as the author envisions is shown above

Our statistics show that chance of catastrophic damage to a unit is once in every one hundred unit-years. We assumed the cost of repairs, capacity charge, and energy charge to be $1,000,000. Three years ago, we experienced major damage to a turbine unit when the main bearings failed to receive lubrication. The cost of the outage was about $1,000,000, and we think that the kind of repetitive checking that a computer can make would have averted this. More recently, we had a furnace explosion which will cost approximately $4,000,000. Rapid sensing and fast computer action probably would have avoided the catastrophe. Still in all, we are not claiming that the computer will avert all disasters, although its inherent ability to keep looking for trouble makes it seem as though it should. We have made our estimate on the basis of averting only one-half of the catastrophes; this has a capitalized value of $250,000.

Fuel costs can be minimized by heat rate improvement due to continuous optimization of variables. Various estimates for savings run as high as 2 per cent; our input-output tests show potential savings of at least 1 per cent. To be conservative, we have taken credit for only $^3/_4$ of 1 per cent savings on the unit. In addition, we believe there is an additional system saving of $20,000 due to dispatching load with more accurate and up-to-date information.

The value of the reduced outage time is estimated at $100,000. We assumed that, by being able to detect a malfunction or a failure sooner, damage would be less, and a shorter outage time would be required. Here again, to keep on the conservative side, we have included only one weekday per year saving. The capitalized replacement energy charge for this one day is $80,000. With a computer, the unit would be put on the line faster; the value of this ability is $20,000.

We show a capitalized saving of $395,000 in personnel. Again, being conservative, we have eliminated only one shift position, at an annual cost of $24,000, or a capitalized value of $200,000. We anticipate eliminating two day-shift men in the Performance Department doing routine calculation for a capitalized saving of $133,000. An additional capitalized savings of $60,000 can be realized by eliminating the conventional acceptance test, periodic laboratory tests, and smaller routine station performance tests.

Unfortunately, there are still some items on which we can't put a dollar and cents value, even though they are bona fide savings. For example, the computer will reduce maintenance costs by detecting equipment failures via rate of change readings and get equipment out of service faster. This should avert, or at least lessen, the scope of costly maintenance jobs, but we have left these savings in maintenance expense as a plus factor. Another example is in the form of deferred savings. If the computer performs as we anticipate, we can materially reduce instrumentation on future units. We might even eliminate the control room as we now know it. Here again, we conservatively called this saving a plus factor.

Savings of $1,215,000 plus some additional indeterminate amount are indicated with an additional outlay of $755,000. This gives a net capitalized savings of at least $460,000 through this next step of automated station operation.

ESTIMATED COST OF AUTOMATION
342–MW UNIT

COMPUTER AND ASSOCIATED EQUIPMENT		$ 560,000
INSTALLATION LABOR		125,000
TOTAL DIRECT COSTS		$ 685,000
FIELD OVERHEADS		45,000
ENGINEERING AND DESIGN		75,000
CONTINGENCY		45,000
TOTAL INSTALLED COSTS		$ 850,000
COMPUTER ELIMINATES NEED FOR:		
DATA LOGGER	$ 90,000	
AUTOMATIC DISPATCH CONSOLE	5,000	
		95,000
TOTAL ADDITIONAL FUNDS REQUIRED FOR COMPUTER		$ 755,000

Fig. 7—The estimated costs for a 342 Mw unit equipped with the digital computer controls the author describes breaks down as shown above

CAPITALIZED SAVINGS OF AUTOMATION
342–MW UNIT

REDUCED POSSIBILITY OF CATASTROPHIC DAMAGE		$ 250,000
FUEL COSTS CAN BE MINIMIZED		470,000
UNIT	$450,000	
SYSTEM	20,000	
OUTAGE TIME CAN BE REDUCED		100,000
FEWER PERSONNEL WILL BE REQUIRED		395,000
OPERATING	200,000	
PERFORMANCE	135,000	
TESTING	60,000	
TOTAL CALCULATED SAVINGS		$ 1,215,000
PLUS FACTORS		
1. REDUCED MAINTENANCE		
2. REDUCED INSTRUMENTATION ON FUTURE UNITS		

Fig. 8—To determine the advantages of this computer control a tally of the expected capitalized savings is put together to compare with Fig. 7

We are on the threshold of a new tool for automated control in the field of general supervision of unit operation. It promises significant rewards. What lies just beyond? The possibility of eliminating the central control room was briefly suggested as an area for further capital savings. In the ultimate, this idea saves the installation and maintenance of our present indicators, recorders, and annunciators so that manual operation will not be possible. Appreciable reductions in operating and instrument maintenance personnel make possible capital cost reductions in service facilities such as cafeterias, office, and locker rooms. When computer techniques now being mapped out are polished and proven, certainly we will be close to these possibilities. Another avenue to savings that digital computers may ultimately offer is the elimination or simplification of some existing analog subloop controllers. Certainly our industry will need to be well grounded in this type of thinking in order to control the generation of power from new energy sources when they become practicable processes. The power industry accepts with pleasure the invitation that sophisticated control offers.

Iron and Steel Engineers Report on Oxygen Assist

At the forthcoming Iron and Steel Convention and Exposition at Cleveland, Sept. 27 through 30, the Association of Iron and Steel Engineers are planning to give considerable attention to the role that oxygen will play in steel making. **E. F. Kurzinski,** manager, and **R. D. Jones,** development engineer with applied research and development div., Air Products, Inc., are scheduled to give a paper "Oxy-Fuel Processes Increase Steel Making Rates." This paper is a progress report on the results obtained to date in the oxy-fuel process (the term adopted for describing the highly rich mixture of oxygen and fuel now employed) wherein roof lances and end lances are used. This paper will also describe the oxy-fuel equipment used, the problems encountered to date, the aims of cooperative furnace programs presently under way and the future potential.

In a brief excerpt the authors stated "Oxygen is the key reason for the present resurgence in thinking of open hearth as the primary steel production furnace for the foreseeable future. Present oxygen practices, coupled with basic refractories, have made possible increases in steel production rates of up to 40 per cent over prior rates without oxygen or basic bricks. A recent development, the oxy-fuel process, promises to double and even triple the steel-making rate of open hearths. This accelerated pace of the open hearth will be made possible by the expanded use of oxygen for combustion and for oxidation of metalloids.

"Oxygen-fuel practices will minimize the scrap meltdown and the refining periods. During scrap meltdown, oxygen is burned with gaseous fuels to provide a flame temperature approaching 5000 F compared to present end burners operating at about 3500 F. Following hot metal, oxygen is introduced at high flow rate to intensify decarbonization.

"The oxygen-fuel mixture is generally introduced by water-cooled lances positioned in the open hearth roof using equipment similar to present oxygen roof lances. This same equipment is then used to introduce oxygen alone. Development work has also been conducted using water-cooled lances located in the furnace end-wall. These end jets are designed for those shops having limited overhead clearance."

In still another paper, one based on an actual installation, "Oxygen Steel Making in the Ajax Furnace at the Appleby-Frodingham Steel Co." **Albert Jackson,** the technical director of Appleby-Frodingham and technical advisor on steel making for the U. S. Steel Co.'s Ltd. of Sheffield, England, had this to say:

"At the end of 1957 the Appleby-Frodingham Steel Co. completely rebuilt a 300-ton tilting furnace so that practically the whole of the steel making operation is accomplished by oxygen lancing. Fuel is only used when charging and fettling and to achieve bath equilibrium, if necessary, when approaching tapping. The reconstruction so altered the furnace design that it cannot revert to its former open hearth steel making practice production levels.

"The second such furnace was commissioned in June 1959, and the third in June 1960. Results are given for the production to date, which is about one million tons. The charge consists of 100 per cent molten iron from an active mixer and contains 1.0 to 1.25 per cent of phosphorus.

"Oxygen used per ton is 1,270 cu ft and fuel 820,000 Btu. The production increase is 50 per cent above that of a modern all basic furnace prior to conversion, and 100 per cent above that of an old silica furnace in which the 'below stage' structure was not of sufficient area to carry the extra fuel firing rate which would have been required to sustain a conversion to an all basic furnace.

"Basic refractories are used for the hearth offtakes and slag collecting chambers.

"After considerable experimental work involving changes in design, the total consumption of refractory bricks has been reduced well below that of comparable standard open hearth practice.

"The furnaces have waste heat boilers and electrostatic gas cleaning plants. They also have two sets of slag chambers and regenerators so that a changeover can be made without taking the furnace off, thus increasing its operational availability.

"The thermal utilization overall, when waste heat steam is included, is much higher than the comparable open hearth practice and compares very favorably with most of the installations at present in use operating the modern oxygen blowing processes."

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost authorities and give specific information which we hope will prove valuable to our readers.

By IGOR J. KARASSIK*

Worthington Corp.

Steam Power Plant Clinic—Part XIX

QUESTION

Your many extremely interesting articles published in the magazine COMBUSTION *under the title "Steam Power Plant Clinic" have been read with considerable benefit to our knowledge of boiler feed pump problems and their solution. We have a problem which would possibly interest you and one on which you could probably give some helpful advice. It is one which recurs with nearly every project, despite our efforts to resolve it. The problem is one of boiler feed suction pipe line vibration.*

We try to run this line straight downward from the deaerator outlet connection and to the boiler feed pumps with a minimum of horizontal run. We have even sloped this line to avoid strictly horizontal piping. We keep in mind the factor of thermal expansion and use flexible spring supports where this factor calls for it.

With piping designed in the general manner, we receive reports from start-up operations of vibration of this piping. Often field forces begin at once to install rigid restraints in order that they may proceed with boiler safety valve setting, boiler boiling out, boiler filling, steam pipe line blowing out and similar operations which generally require low and erratic flow conditions of the boiler feed pumps. The consulting engineers receive complaints and requests for added restraints to hold the piping rigidly. Often such restraints are installed by field forces entirely neglecting the effects of such on thermal expansion. These restraints do reduce the vibration but the cause remains. We would like to formulate design criteria for this piping which would react without vibration to all flow conditions. We realize that this is a very large order. Pumping a flashing liquid is indeed a difficult service for a pump, especially with varying flow conditions and a varying head (floating deaerator pressure). The reaction of many engineers to this problem is to tie down the piping and let the effect continue. I feel that there surely must be a better answer to this problem. Your comments on this matter would be greatly appreciated.

ANSWER

You could have hardly chosen a subject that interests me more or a question that is more difficult to answer conclusively than that dealing with vibration in the suction piping. I am not sure that it is possible to present an exhaustive treatment of this problem, because so many different causes may contribute to what appears to be the same effect.

Nevertheless, I may be in the position to suggest certain areas of exploration which should in many cases serve to pinpoint the problem. I have in mind two specific instances in which I was personally involved and which I can, therefore, document quite thoroughly. I refer to these two instances as cases "A" and "B."

Case "A"—Suction Line Vibrations

The installation consisted of three boiler feed pumps, each designed to handle 400,000 lbs per hr of 312 F feedwater against a discharge pressure of 2200 psig. The pumps take their suction from a deaerating heater. They are driven by electric motors through hydraulic couplings at variable speeds. Two pumps feed the boiler, the third remaining on standby service. The three pumps are exact duplicates of three other pumps installed earlier to serve a duplicate main unit in the same station.

Shortly before being placed in service, the individual pumps were all tested with the recirculation line open and no flow to the boiler. Severe vibration was experienced in the piping, at all discharge pressures from 500 to 2000 psi, the amount of vibration increasing with the pressure. It was noticed that the vibration ceased when the line to the boiler was opened, even if flow to the boiler was just nominal. The vibration was most noticeable in the suction piping and while some discharge piping vibration did occur, it was eliminated after pipe hangers were relocated and secured. The vibration was accompanied by a rather rapid fluctuation of suction pressure, which varied from 40 to 60 psig.

The bypass orifices in the recirculation lines had been rated at 75,000 lbs per hr. The first conclusions reached in the field were that the pumps had an unstable head-capacity curve, although no evidence of such an instability had been shown during the shop tests of the pumps. It was therefore decided that increasing the minimum flow through the pumps might eliminate the cause of vibration and pressure fluctuation. Accordingly, a $^1/_2$ in. bypass line was installed around the orifice in

* Consulting Engineer and Manager of Planning, Harrison Div.

order to permit increasing the minimum flow. The valve in this 1/2 in. line was cracked open, passing something of the order of 30 or 50 gmm in addition to the flow through the orifice. Immediately, the vibrations disappeared.

This experiment was considered to be sound circumstantial evidence of the instability of the head-capacity curve. The original orifices were replaced by new ones rated at 250 gpm, in other words of slightly more capacity than the sum of the original orifice rating plus the flow through the 1/2 in. bypass line. To everyone's surprise, the vibrations returned. They again disappeared as soon as the valve in the 1/2 in. bypass line was cracked open.

This definitely disproved the theory of an unstable curve and indicated that some sort of a "resonance" problem existed. Such a conclusion was reinforced when one recollects that with the original 75,000 lbs per hr orifices vibration ceased the moment the line to the boiler was cracked open, changing the configuration of the hydraulic circuit.

In addition, it became noted that the vibration would occur only if the pumps had been idle or even drained out prior to a run. If the pumps were operated for 12 to 24 hr on normal operation, that is feeding the boiler, return to minimum flow conditions did not cause vibration or fluctuation of pressure. The theory was developed that the piping permitted the trapping of some quantity of air which acted as a resonant spring and led to a pulsating condition. After operating for a number of hours, the air would be washed out of the lines and the condition disappeared. Circumstancial evidence indicates the probability of the theory: the original size orifices were reinstalled and the vibration never reoccurred after the unit was placed in regular service. The pumps have been operating for close to three years and even with no flow to the boiler and all flow limited to the bypass recirculation, there is no sign of distress.

Case "B"—Suction Line Vibration and Apparent Instability of Operation

Two full-capacity turbine driven pumps are involved in this installation, either pump delivering full flow to the boiler and the other pump remaining on standby duty. Each pump is designed to handle 1,600,000 lbs per hr of 270 F feedwater against a rated discharge pressure of 2720 psi. Feedwater control is maintained by varying the steam turbine speed.

Two separate and distinct conditions of vibration or instability were observed during the initial stages of operation. The first involved violent piping vibration and pressure fluctuations when the pumps were operating with a closed discharge valve or against a closed check valve and any flow through the pump was limited to the recirculation through the bypass. It was observed that when such vibrations took place, it sufficed to crack the valve to the boiler just slightly to stop the vibration. These vibrations *did not* recur after the pumps went into regular operation.

The second involved equally or even more serious vibrations which took place whenever the second pump was brought on the line and the pump which was running was backed off manually prior to shutdown. If for instance one pump was handling 1,200,000 lbs per hr and the second pump was started and brought on the line to operate in parallel, the two pumps split the load at 600,000 lbs per hr each and ran quite smoothly. If at this point, one of the pumps was put on automatic control and the second one backed off manually, violent vibrations started when the second pump was reduced to about 400,000 lbs per hr. These vibrations were so dangerous that the operators were forced to bring the pump to rest as rapidly as possible. On the other hand, if the bypass on this second pump was opened manually when the flow was down to 500,000 lbs per hr, the pump could be brought down slowly without untoward difficulties.

These circumstances were the subject of extensive analysis and discussions which resolved the problem in a manner sufficiently clear to be conclusive.

The clue to the solution lay in the fact that the two types of vibration were apparently caused by completely contrary conditions. In the first case vibration was stopped when the pump delivered even an insignificant amount of water to the boiler in addition to the bypass flow. In the second case, the vibration stopped once the check valve was closed and the only flow was through the bypass. This observation and the similarity of this case with that of Case "A," led us to the conclusion that the first vibrations were due to the presence of air in the system. Conclusive additional proof was made available from the fact that air vents were subsequently installed ahead of the individual pump check valves and this type of vibration disappeared completely.

The cause of the second vibration was explained very readily. While the pumps have a steady rising

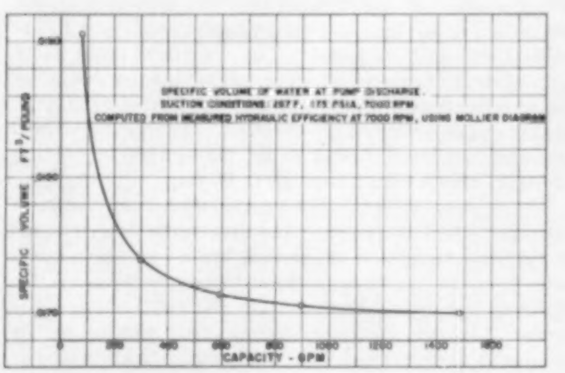


Fig. 1—Rise in specific volume or decrease in specific gravity of the water within a pump as its flow is reduced and efficiency dropped

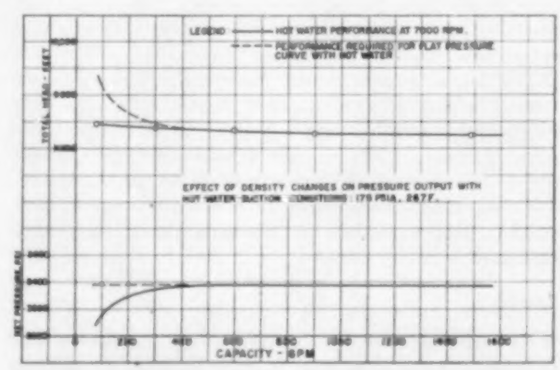


Fig. 2—Reduction in specific gravity (Fig. 1) has its effects upon pressure generated by the pump

characteristic curve expressed in feet head, the heating up that takes place within the pump changes the feed-water temperature (and hence its specific gravity) during the passage through the pump. The effect varies with pump flow–of course being more pronounced as capacity and efficiency are reduced.

This effect is illustrated graphically by the curves in Figs. 1 and 2. The first shows the rise in specific volume (or decrease in specific gravity) corresponding to the reduction in efficiency with reduced flow. The second illustrates the effect of this reduction in specific gravity on the net pressure generated by the pump and expressed in psi. It will be noted that despite the fact that the *total head in feet* is not unstable, the *pressure in psi* developed by the pump begins to drop off at flows below 800 or 750 gpm. This makes parallel operation at these flows impossible.

This effect, of course, is entirely independent of pump design and occurs with all centrifugal boiler feed pumps. Fig. 2 shows the type of *total head curve* that would be necessary to develop in order to have a steady rising *net pressure curve*. This, of course, is not possible with a centrifugal pump, and parallel operation in the range where the specific gravity effect causes such a reduction in net pressure is not practical.

If the bypass is opened before the flow drops below 500,000 lbs per hr, the check valve closes as soon as the pump which is being slowed down develops less pressure than the pump on automatic control and no longer reopens. The pump is then capable of being brought to rest at leisure and without vibration. It was agreed that whenever the pumps have to be switched, operators would open the bypass on the pump being brought down at 500,000 lbs per hr. No further trouble has taken place since.

The conclusions reached were that the pump performance was not and had not been responsible for either the vibrations or the flow fluctuations and the pumps were given a clean bill of health.

General Comments

I would suggest that you conduct a study to determine whether the type of vibration which has been reported to you has any similarity to the two cases I have outlined.

As to the question of flashing under conditions of sudden load drops, that is an entirely separate matter and one which—today—should present no particular mystery. I have conducted extensive studies on this matter and I believe that there is no longer any reason why a group of boiler feed pumps, the deaerator and the suction piping configuration should not be so selected and so arranged that flashing difficulties are eliminated under any transient condition that can be expected to occur. A complete treatment of this subject appears in a group of articles based on a paper presented before the ASME in 1953.*

* "Centrifugal Boiler Feed Pumps Under Transient Operation Conditions" by Igor J. Karassik, George H. Bosworth and Warren D. Elston, presented at ASME Fall Meeting, October 1953, Rochester, N. Y. (Worthington Reprint RP-961)

Vallecitos Boiling Water Reactor Restarted

The Vallecitos Boiling Water Reactor (VBWR) recently went "critical" again after being shut down since Oct. 1, 1959, for a scheduled $1 million modification.

Initial power operation will begin in two or three weeks, after the "critical" tests and tests to check maintenance work performed on the turbine.

The reactor is presently operating with a core mainly composed of fuel assemblies for several Atomic Energy Commission programs, including a fuel development program for Consumers Power Company's Big Rock Point, Mich., nuclear station.

The startup core contains test fuel assemblies similar to those being used in the Dresden Nuclear Power Station.

VBWR originally was designed to develop data for application in the design of the recently completed Dresden Nuclear Power Station, world's largest operating atomic electric power plant, and for other developmental programs. General Electric designed and built the 180-mw Dresden station for Commonwealth Edison Company and the Nuclear Power Group, Inc.

The Company-financed modifications were undertaken to permit the reactor to be used for advanced experimental programs relating to other nuclear power plants, and to general technological development of nuclear power. One such program is the Fuel Cycle Development Program being conducted for the AEC.

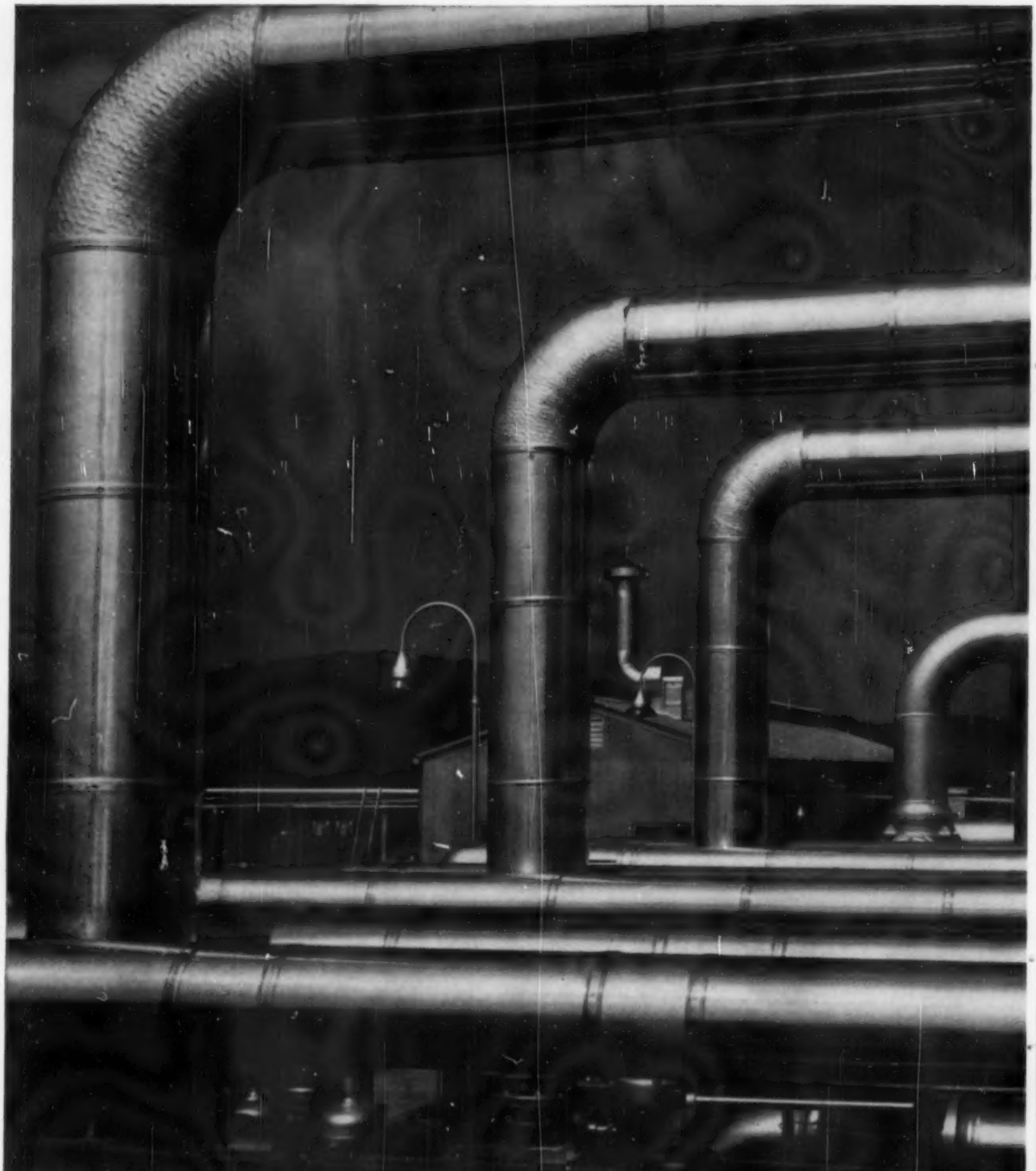
Experience gained during the conversion program—one of the few times a power reactor has been torn down after lengthy operation—indicates that radioactivity will not be a serious problem in the maintenance of boiling water reactors. Radiation levels in the reactor building—except in the area formerly occupied by the reactor core—were sufficiently low to permit modification crews to work full shifts with easily controlled safety precautions.

Major changes to the reactor were a new core structure, and the installation of two high-head pumps to increase the circulation rate of the cooling water. The two high-head pumps which replaced a single low-head pump, double the circulation rate and permit testing of higher specific power fuels.

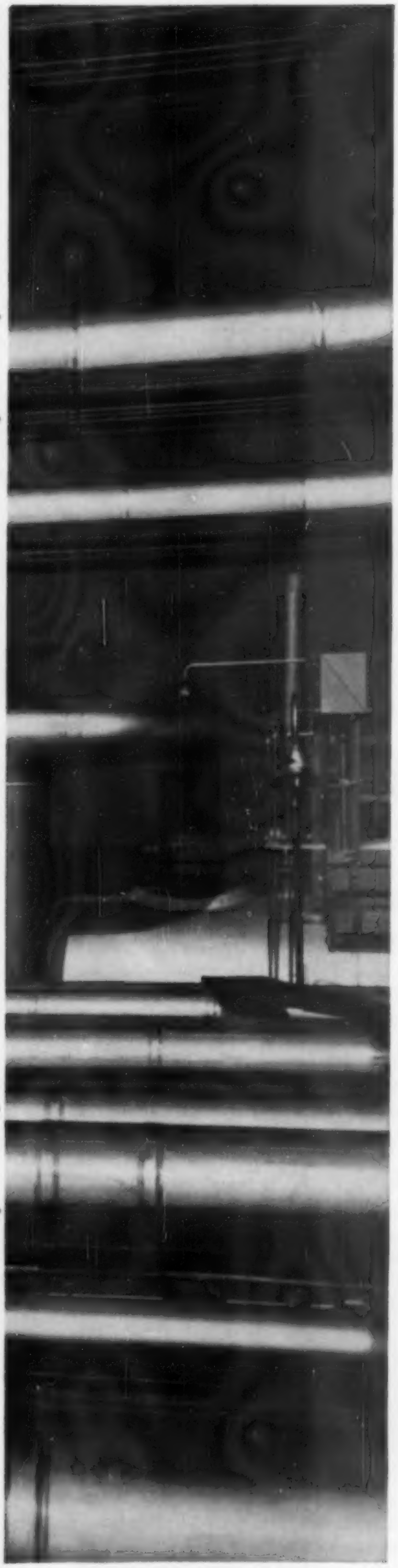
The new core structure permits better steam-water separation, and allows a higher percentage of the cooling water to pass through the fuel elements. It also broadens the performance limits of the reactor when employing internal natural circulation, forced circulation, or single or dual-cycle operation.

These two changes give engineers the capability to simulate the characteristics of a large power reactor from the operation of a relatively small, compact core in the VBWR.

Other features incorporated in the modified reactor are a control system capable of providing large-scale fuel irradiations up to 20,000 megawatt-days per ton, and instrumentation installed in the core for testing fuel designs and core performance.



PHOTOGRAPHED AT NEW YORK STATE NATURAL GAS CORPORATION'S LEIDY COMPRESSOR STATION, TAMARACK, PA.



Installation time at Leidy Station cut 25% with prejacketed J-M METAL-ON® pipe insulation!

"ALMOST 2 MILES OF METAL-ON PROTECTS OUR OUTDOOR PIPELINES. THIS IS THE BEST—AND BEST-LOOKING—INSULATING JOB I'VE EVER SEEN,"

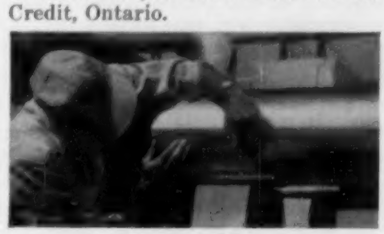
says head station engineer VICTOR CUMMINGS

Leidy Pool, with an ultimate storage capacity of 105.6-billion cubic feet of natural gas, is served by a compressor station incorporating almost two miles of outdoor pipelines. Both lines and equipment must be completely protected against northern Pennsylvania's violent winter storms, torrential spring rains and summer heat. Metal-On jacketing, developed by J-M, was chosen to handle this difficult job.

Metal-On is prefabricated at the factory in 36-inch lengths. Each length combines high-temperature J-M Thermobestos insulation . . . a moisture barrier . . . and a special aluminum alloy jacket. And because each length can be applied in one simple operation, erection time savings at Leidy averaged 25%! Metal-On can also be easily cut on the job with portable power or hand saws. Cutouts for hangers and supports are simple to make.

Maintenance savings can be very impressive, too. Metal-On doesn't corrode, needs no painting. The rugged jacketing, combined with a locking device that snaps closed and seals joints, will lock out weather and moisture permanently. And each section can be easily removed for trouble-shooting.

You may not have *two miles* of pipeline . . . but if you have a tough outdoor insulation problem, it will pay you to investigate J-M Metal-On. Just write to Johns-Manville, Box 14, New York 16, N. Y. In Canada: Port Credit, Ontario.



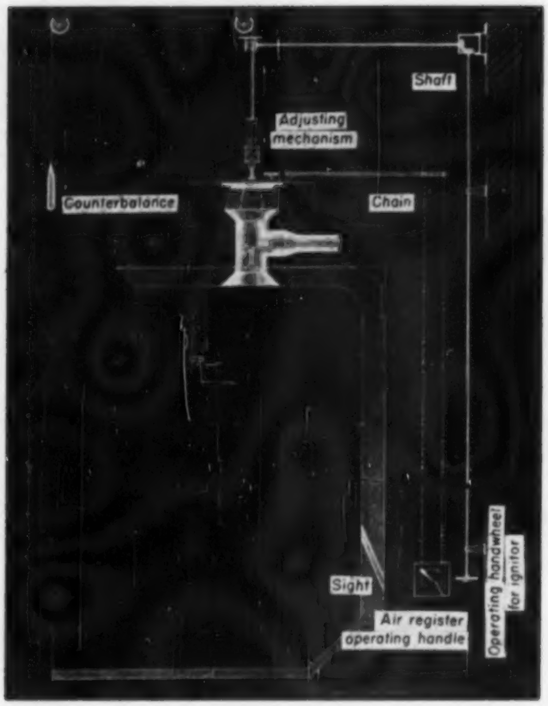
METAL-ON: JUST MINUTES FROM CARTON TO PIPE!

JOHNS-MANVILLE

AN INSULATION FOR EVERY COMMERCIAL AND INDUSTRIAL USE

JOHNS-MANVILLE JM PRODUCTS

The chains and shafts of the remote burner and ignitor control of years ago established the basis for . . .



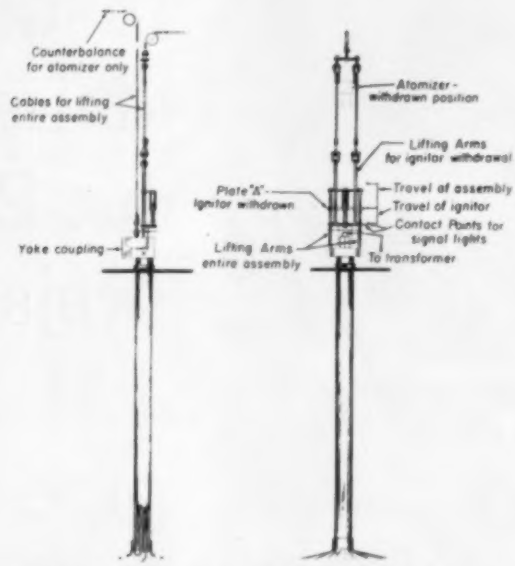


Fig. 1, above shows arrangement for remote burner control of twenty years ago and Fig. 2, above shows ignitor details

The Development of Remote Fuel Burner Control

One of the oldest and most experienced of remote burner light-off sequence and safety control system manufacturers discusses its approach to the automatic boiler plant demands of today and tomorrow—a flame proven ignitor as a basic component to fit into any well engineered control system.

By JOHN DUNN*

Peabody Engineering Corp.

REMOTE burner light-off and control systems with retractable ignitors were developed and used commercially by our organization over 20 years ago and met fully the demand for a convenient method of placing roof-fired boilers in operation (see Fig. 1). The demand stemmed from difficulty in manually lighting off and adjusting burners located in a relatively inaccessible area, usually near the roof of the boiler room, where temperatures were high and ventilation poor. What we are now endeavoring to do with television, flame sensing devices and elaborate electrical circuitry was then safely and effectively done with chain, cables, pulleys, sighting tubes, levers and light oil-electric ignitors. Visual flame supervision for both ignitor flame and main flame was accomplished by sighting through tubes at operating floor level. Burner and ignitor adjustments were made by levers or wheels at the remote control station on the firing floor. These levers or wheels were connected to the operating gear of the ignitors or burners by sprockets, chain, shafts, levers and counterweights.

As crude as these early systems were they did the job, saved labor, eliminated the need for continuous supervision at burner level, improved working conditions and increased safety. The components were rugged, dependable, simple and their operation was positive. Boiler capacity was low by today's standards so that burners could be selected, spaced and arranged in a position to permit easy checking of the operation of the various controls by observation of the displacement of the gears, levers, etc., of the control system. The light oil ignitor used was stable, positive and dependable and proved to be the essential component for successful system operation. The ignitor did, however, require periodic removal for the cleaning of the atomizer tip.

Remote burner light-off and control systems would have advanced far more rapidly if the roof-fired installations had retained their brief popularity, as the components going into these crude but effective systems would then have been refined and improved to comply with our changing ideas, modern methods and increased capacities. As it was the program all but died through lack of demand until larger boilers utilizing large numbers of widely spaced horizontally fired burners at numerous

* General Sales Manager of Peabody Engineering Corp. and Vice President, Peabody Engineering Corp., of Canada, Ltd.

. . . *What a suitable gas electric ignitor must have today to make the automatic boiler plant possible*

1. Absolute stability to provide igniton under any operating conditions.
   - (a) Unaffected by changes in windbox pressure up to the full static capability of the combustion air fan.
   - (b) Unaffected by burner register design or adjustment.
   - (c) Unaffected by adjacent burner ignition or shut down.
   - (d) Unaffected by changing combustion air temperature.
   - (e) Unaffected by main burner capacity.
   - (f) Unaffected by the kind of main fuel being fired.
   - (g) Unaffected by furnace temperature.
2. Dependable flame proving.
3. Safe prevention of false shutdowns from momentarily interrupted ignitor gas supply.
4. Little or no maintenance.
5. Separate clean instrument air supply unnecessary.
6. Ability to use relatively low pressure windbox air or air through the burner register or a combination of both regardless of type of air heater or air temperature.
7. Operation over a wide range in gas pressure.
8. Self cleaning (will not be fouled by main fuel being burned).
9. Ability to operate in various locations in the burner throat.
10. Freedom from any effect produced by radiant heat from main burner flame.
11. Fail safe.
12. Flame proving device insensible to any flame except the proving flame.
13. Ease of installation.
14. Simplicity in design so that any operator can understand its operation.
15. All major elements removable while furnace is under fire.
16. To be operable only during the ignition period in a safety-sequence system, but to be suitable for continuous operation.

and Flame Protective Systems

operating levels were introduced. These boilers required burner operation from a single control point to reduce the complexity and manpower required in getting on the line. The hardware developed for the old installations, although rugged and safe, could not be used for the new requirements. The size, location and number of burners precluded sighting by tubes. The use of cable, gears and chain on a modern boiler would result in a maze on the boiler front and operating floor. Accessibility would be difficult if not impossible. The advantage of being able to check each action visually from the control point to the burner and ignitor operating gear (see Figs. 1 and 2) would be lost.

The Changing Demands

As natural gas became available throughout the country gas-electric ignitors were in demand to replace the light oil ignitors, not only on gas-fired units but for oil and coal-fired units as well. The cleanliness of the gas fuel, the simplicity of application and the fact that frequent inspection and cleaning were not required all contributed to the demand. Unfortunately, however, *the demand preceded the product development.* It was soon discovered that unsupervised gas-electric ignitors could be a source of trouble and a hazard due to their own unstable characteristics under the variable required light-off conditions.

A degree of success was achieved with these units for *manual* light-off at the burner front where the operator viewed and checked both the ignitor and main burner flames through the burner observation port and made certain the ignitor was extinguished after main burner flame was established. To permit satisfactory application of gas-electric ignitors to *automatic* unsupervised operation various means for flame proving were tried which would shut off main burner and ignitor fuel if the ignitor failed. Ignitor flames were first proved with flame rods, then scanners, or combinations of both. Now, for ignitor service, redesigned flame rods are back and have proved most adaptable since they indicate only ignitor flame at the rod and not flame elsewhere in the furnace. While the flame rods effectively prove flame and can shut off the main burner and ignitor fuel supply on flame failure a problem developed with the unstable characteristic of the ignitor flame itself. This problem proved to be the false or nuisance shutdown which, depending on how the ignitor was tied into the system, could shut an entire boiler unit down in the absence of actual flame failure. The rush or even inability to get back on the line promptly after such shutdowns has sometimes proved disastrous.

Means for proving ignitors, other than flame rods, have been tried without success or positive contribution to the development of remote automatic control for large multi-burner boilers. On the surface it appeared to many interested in establishment of automatic controls that if ignitor and main burner flames were proved and upon flame failure, fuel to burner or furnace were shut off, a control unit would be safe. This thinking then led to an almost universal demand by various insuring and governing bodies for the installation of flame sensing equipment that would perform along these lines. What was ac-

complished, however, was to add gadgetry to a component basically unstable and hence unsound. In time, due to inherent instabilities, many ignitor installations were removed or bypassed to preserve continuity of operation. Fortunately ignitor designs were being improved and, with some limitation, satisfactory systems were developed for the small, single-burner industrial boiler.

Small automatic boilers of the package type were being developed along with single automatic burners. For this boiler service with burners under specific predetermined start-up conditions, the gas-electric ignitor established that it would safely light off the burner, prove ignition flame and allow the establishment of main burner flame at *low fire start*. This was no miracle as the predetermined safe start conditions could be reproduced time after time. Without the satisfactory flame proven ignitor, however, the single automatic burner would not be here. By the same token, without the development of a satisfactory flame proven ignitor, a safe, automatic or remote light-off system for multi-burner furnaces cannot be achieved. (See A.S.M.E. Paper 58-A-279* "Application of Existing Flame Protective Equipment to Oil and Gas Burners.") The flame proven ignitor is in fact the heart of the system.

Developing a Safe Ignitor

With this in mind the authors company reviewed the history of over 20 years of its experience in this field and set forth the requirements for a suitable gas-electric ignitor as shown in table on p. 47.

With these objectives in mind an extensive research and development program was conducted at our plant and later in the field; in Los Angeles, for gas and oil firing and in St. Louis for pulverized coal fired burners.

This program has produced an ignitor, Fig. 3, which meets the specified requirements—the Peabody FP (Flame Proven) Ignitor. It was offered to the Public Service Electric and Gas Company of New Jersey for a field test at their Bergen generating station to meet their need for such a unit. The ignitor was tested there in two locations, one centrally located on the axis of a circular multi-fuel type burner and the other angling down through the windbox, terminating within the burner at the windbox edge of the throat.

* Presented in New York, Nov. 30-Dec. 5, 1958.

Field Tests

The initial tests were conducted with the ignitor in the centrally located position in a main burner. These tests were designed to determine the ignitor's ability to light reliably from a remote location and to prove the flame. Ignition gas pressures were varied from 1 psi to 18 psi with windbox to furnace differential pressures of 1-in. H_2O to 6-in. H_2O. Air registers were set in three different positions, 15 per cent, 50 per cent and 75 per cent open. In this series of tests the ignitors proved reliable in their ability to light under any combination of conditions and to prove the flame under these conditions.

The next series of tests was conducted with the ignitor installed in the side position of the main burner. The ignition gas pressure was 13 psi. In these tests the ignitor would light and prove flame dependably with the registers in the 15 per cent or 50 per cent positions and with varying windbox differential pressures. The air velocities of the 75 per cent register settings were, however, too severe and would not permit positive flame proving.

The final phase of the program was to test ability to prove flame with the ignitor in service along with the main gas flame. These tests were conducted with the ignitor in the center position only. It was determined that it was possible to detect the ignitor flame with the main gas burner in service over a wide variety of conditions.

The FP ignitor, Fig. 3, 4 proved suitable for Public Service Electric and Gas Company, who now have in operation 24 of these ignitors installed on one of their boilers and are in the process of installing 72 more on three other boilers.

Ignitor Operation

In operation (see Fig. 4) ignitor fuel gas is passed through a strainer and into a gas supply pipe within the ignitor tube. The gas then enters a hollow distribution chamber relatively close to the ignitor tip. This chamber requires the gas stream to divide. One stream passes directly to one or more open ended main ignitor gas tubes which are used to supply fuel for the main ignitor flame. The remaining gas stream makes two right angle turns before entering a gas spud supplying

Fig. 3—FP (Flame Proven) gas-electric ignitor, which the author's organization has developed

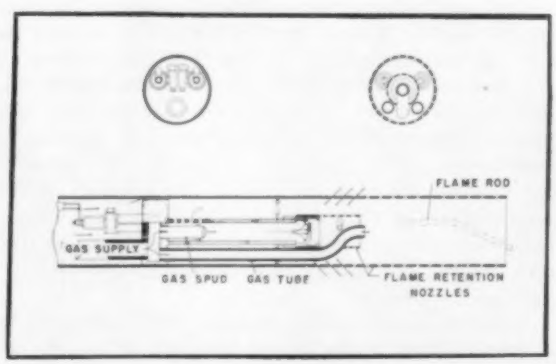


Fig. 4—Sectional drawing of FP gas-electric ignitor, Fig. 3, (patent applied for) labels the working parts

gas for a primary ignitor flame. This method of introducing gas to the small orifice in the spud eliminates the passage of any contaminants to the primary stream. Any dust, dirt or other particulate matter passing through the strainer flows directly to the wide open main ignitor gas tubes. Only clean gas passes through the small spud orifice. The gas from this orifice inspirates combustion air to produce a primary gas-air mixture which is ignited within a perforated sleeve, forming a primary ignitor flame retention nozzle, by means of a spark established between the electrode and periphery of the nozzle. This primary flame ignites the main ignitor gas to form a flame which originates within a second perforated sleeve, forming a main ignitor flame retention nozzle, and bathes a high alloy temperature-resistant flame rod. The inner and outer perforated retention nozzles protect both the primary and main ignitor flames from high velocity air introduced through the burner register or windbox over a wide range of angles or velocities. This unique design feature provides (1) a rich *primary* ignitor flame, doubly shielded by its two stage retention nozzle and the main ignitor flame retention nozzle, and (2) a rich *main* ignitor flame shielded by its retention nozzle to give the absolute optimum in ignitor stability.

A feature has been incorporated in this design to avoid the objectionable false or nuisance shutdown due to momentarily interrupted ignitor gas supply. The main ignitor flame established within the perforated main ignitor flame retention nozzle will bathe the flame rod to complete a circuit and hold open the ignitor gas solenoid supply valve. If, due to interruption in this gas supply by reason of severe reduction in gas pressure or air or scale in the ignitor gas line, the ignitor momentarily loses ignition, the electronic relay automatically re-establishes the spark for reignition purposes. If the ignitor then fails to reignite within a limited pre-set time interval then and only then will it shut down. Upon the re-establishment of main ignitor flame the spark will again be cut out. The spark is on only when required for igniting the primary ignitor gas stream and is shut off after the main ignitor flame is established. In this way the life of the electrodes is extended indefinitely in comparison with ignitors utilizing the continuous spark principle. The ignitor, in a safety sequence system, shuts down when main burner flame is established.

The construction of the ignitor itself is simple and rugged. All major parts can be easily withdrawn while the burner or furnace is in operation. Air sealing is provided for withdrawal from pressurized furnaces. The ignitor and the control box illustrated are not integral but can be separated so that the control box can be located at any remote control point. The ignitor tip end assembly is arranged to prevent back-eddies from the main burner flame which might otherwise result in fouling when burning coal. Dense, high dielectric strength insulators suitable for the temperature level are used for both the electrode and flame rod. These insulators are short, suitably spaced and mounted to provide support for the flame rod and electrode. These elements connect to the boiler room side components in the control box with special high temperature, glass-insulated wire.

With the successful development of a satisfactory ignitor as the heart of the remote burner light-off and control system the coordination of the various other system components can now go forward to achieve electrically what we accomplished mechanically 20 years ago. Levers, chain and rods are replaced with electric motorized operators, valves and dampers. Main flame observation ports and ignitor sighting tubes are replaced with main burner flame scanners, television and ignitor flame proving rods. Push buttons replace operating levers and electrical indicators replace operating quadrants. Now one man at a central remote control station can see and visually check burner operation more effectively than an operator or group of operators stationed at the boiler front. Fig. 5 shows a typical remote control panel.

The flame proven gas-electric ignitor is essential for unattended boiler operation. Also the flame proven oil-electric ignitor with its inherently stable characteristics has been further developed and refined to meet today's more exacting demands. (See Fig. 6). This unit, however, has the disadvantage of requiring periodic removal for cleaning and changing the atomizer tip, and thus is not adaptable for long periods of unattended operation.

Through the development of rugged, stable, positive and dependable flame proven ignitors a major contribution has been made to the development of the automatic steam power plant. However, there still is a need for further development in supervisory and anticipatory controls to allow the ultimate goal of the complete, safe, unattended, fully automatic steam plant.

Fig. 5—Typical station for remote burner light off

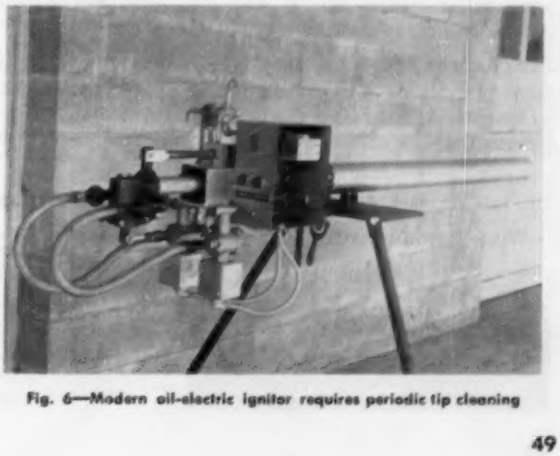


Fig. 6—Modern oil-electric ignitor requires periodic tip cleaning

Technical Book Reviews

By John H. Cruise

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

The Diesel Engine

By L. V. Armstrong and J. B. Hartman

$8.75, 360 pages

This text is subdivided into chapters as is common to most books, but basically it is different in its presentation in that each chapter is edited by an authority in subject matter.

For the edification of the reader, at strategic points, a "base design problem" is injected, pointing up the practical value of the theory involved.

The subdivisions are headed: general, combustion, dynamics, statics, parasitics, and economics. The appendix contains the problems referred to in the subdivisions.

Illustrations, graphs and photographs are used extensively.

This book should be welcomed by student, operator and designer, as it is broad enough to overlap all phases.

American Petroleum Refining

By H. S. Bell

$12.50, 538 pages

This book shows the know-how of modern refinery processes and equipment. It includes information on chemical and physical properties of hydrocarbons, crude oil and oil products and the relation of auxiliary service to the main plant.

Flow charts and operating data are complete.

The book is written to give broad coverage for technological information on the refining branch of the industry.

The subjects covered are: history on the growth of the industry, crude oils and their properties, distillation, heat transfer, fractionation, pipe heaters and condensers, cracking—thermal and catalytic, dewaxing and solvent extraction, filtration, blending and compounding, storage, evaporation and service requirements.

Nuclear Fusion

Edited by Dr. William P. Allis

$12.50, 488 pages

A carefully worked out presentation of world wide information on "nuclear fusion" from all the papers presented at the Second Geneva Conference.

The topics covered are: controlled thermo nuclear reaction in the U.S.A., the United Kingdom and the U.S.S.R., plasma diagnostics, equilibrium, stability and dynamics, interaction with electro-magnetic waves, pyrotrons, ring discharge, injection machines, stellators, dynamic and sustained pinches.

There is liberal use of graphs, photographs and diagrams with detailed mathematical analysis.

Note:—The information contained in this book is all in the field of nuclear physics and is far beyond the scope of the average engineer.

A Directory of World Activities and Bibliography of Significant Literature on Applied Solar Energy Research

Edited by Jean Smith Jensen

275 pages, no price furnished

Applied Solar Energy Research is intended to supply a central catalog of world literature on applied solar energy and of laboratories and individuals at present active in this rapidly expanding area of research.

It is not exhaustive, as items of ephemeral interest have been omitted, but all genuinely important papers have been included.

A partial list of the subject matter listed is: solar energy—the fuel situation, solar radiation, the use of solar radiation as heat, the use of solar radiation as light.

Flames—Their Structure, Radiation and Temperature

By A. G. Gordon and H. G. Wolfhard

$14.00, 383 pages

The aim is to give advanced discussion of a part of the field concerned with stationary flame with emphasis on the physical process occurring in the flame, rather than the chemical viewpoint.

The subjects covered are: premixed flame, flow pattern and shapes, measurements of flame velocity, mechanics of flame propagation, diffused and unstable flames, solid carbon in flames, radiation processes, flame temperature measurements, ionization and combustion processes.

This is probably as complete a treatise devoted to this field as could be obtained and is without doubt outstanding.

Five Fundamentals that make . . . .

. . . . Interesting Technical Papers

First hand observation of many meetings has prompted COMBUSTION to offer some convenient guides for future speakers and to call attention to the response enjoyed by one who broke with the conventional in giving his talk.

FIVE VITAL STEPS TO A SUCCESSFUL PAPER

INVITATION
ORGANIZATION
ILLUSTRATION
ACCOMMODATION
PRESENTATION

IN OUR April editorial, p. 41, we discussed the possibilities of more lively and interesting technical sessions at Engineering Society Meetings. The idea was to improve presentations by leaving the historical and statistical aspects of a paper to prior reading by members. The author would then be free to drive home his main points in a more informal and appealing manner. **Mr. R. T. Ellington**, Asst. Research Director of the Institute of Gas Technology, tells us that the Society of Petroleum Engineers of AIME follows a procedure similar to the World Power Conference, Canadian Section, which we recommended. Unfortunately, according to Mr. Ellington, AIME speakers are still permitted to follow the written paper too closely.

Mr. Basil Payne of Central Maine Power Co. wrote us that he intended to follow our suggested approach in presenting his paper at the Northeastern District Meeting of AIEE. We went to Providence, R. I., on May 2 to hear Mr. Payne and were delighted with his presentation. We found his talk interesting, easy to follow, lively and the occasional humorous interjections were most effective. Feeling that our own opinion might be biased we interviewed five of Mr. Payne's audience to check our own reaction.

The questions were:

1. Were you aware of any difference in the way Mr. Payne's paper was presented as against the average technical paper?
2. Did you find it easier listening than the average paper to any appreciable extent?
3. Did his principal points come home to you?
4. Do you have any thoughts on how the formal presentation of technical papers could be made more interesting or fruitful?

The revealing answers to these questions are presented below.

SUBSTATION SUPERINTENDENT
ELECTRIC UTILITY

"The story idea made this paper much more interesting. This was much easier listening than the average straight technical paper.

"Yes, his main points came home very effectively.

"I think only a small percentage of highly technical design people use a down to earth approach which hits a happy medium between design and operating people."

REGIONAL SALES MANAGER
ELECTRIC EQUIPMENT

"Yes, I think he tried to lighten up his paper and to make it not quite so dry and draggy.

"Yes, it was much easier to listen to—it had life to it—spirit.

"It was a good review and I think all his points came across well.

"Presentations could be improved by speakers acting as though they were really interested in their subjects Too often I sense a 'let's get it over with' attitude."

ENGINEER
ELECTRIC UTILITY

"The paper was more fundamental than many. The vector diagram for example was something people need to be reminded of.

"I think it was about the same as the average paper. Maybe omitting all the history made it smoother.

"Yes, I got the message.

"Papers could be bettered by stating the fundamentals and defining units. For specialists to assume we have these at our fingertips is wrong. This would not be talking down to an audience. It would be recognizing the generalized makeup of the audience."

RETIRED
UTILITY ENGINEER

"Yes, first of all everyone had a copy of the paper. He hit the high spots and didn't rehash things. I thought it was good and pleasant listening.

"Yes, it was more interesting.

"Sure his message was easy to follow.

"Improving papers—that depends on the individual. A technical man wants special technical information and operating men want general or application know-how. We need both kinds of men so we need both kinds of papers, I think. Its awfully hard to please both groups with one paper."

Sales Engineer
Electric Equipment

"Yes, I was gratified when Mr. Payne said he'd leave the history and details for later reference for those who were interested. I think this is an excellent idea—details just cloud the main points and conclusions.

"Yes, I think the presentation and delivery was good.

"I understood the main points even though this is not my strong subject.

"I think we'd have better presentations if authors had some public speaking training—like with Toastmasters for instance. Most people are interested in a concise paper where the problem, approach and conclusions are stated briefly and clearly. I think most talks are too long. Supporting material should be left to reading the paper. After all these aren't college lectures. I think 15 minutes is enough for average material."

The Ingredients of a Successful Paper

The comments of these listeners indicated general agreement that Mr. Payne's paper had been presented in an interesting and appealing manner. Because of an easy-to-take presentation the message had gotten through to his listeners. The function of communicating knowledge—essential to the complete engineering career—had been successfully accomplished.

This story might well be concluded at this point but to do so would be to oversimplify the problem. We have discussed a single aspect of only one of the five ingredients of the successful technical paper. In chronological order these are:

1. Invitation
2. Organization
3. Illustration
4. Accommodation
5. Presentation

All of these ingredients are important. Their relative values may vary with subject matter, audience or type of session, so we shall not attempt to stress any prime ingredient except to point out that the first four all build toward the presentation.

Invitation

The invitation to present a technical paper presumes a number of important points. First, the invitation presupposes that the proposed author is a competent authority in the designated field. This in itself is recognition of professional achievement and the reaction ought to be one of gracious response to a compliment; not assumption of an onerous chore. The latter attitude prevents many papers from attaining anything better than distinguished mediocrity. To those presenting papers for the first time the invitation should not be the signal for a prolonged attack of panic and jitters. Papers committees know their business and if they didn't feel you were qualified to do the job they wouldn't have asked you.

Invitations also impose a very definite responsibility on the group issuing the request. The proper invitation should:

1. Include full particulars on time, place, location, sponsoring group, type of meeting, length of time for presentation, information on other invited authors, projection and audio equipment available, and papers for the same program.
2. Be accompanied by a copy of the society's author's guide or equivalent.
3. Include a complete time schedule for processing the paper (through reviewing committees, preprints, etc.)
4. Convey to the author detailed information on the meeting room—length, width, ceiling height, arrangement, electric current characteristics, etc.
5. Designate the individual the author should consult for further information.
6. Outline the objectives of the society and the session.
7. Indicate whether funds are available to assist the author who might otherwise be unable to participate.

Organization

The organization stage is critical. The work done here determines whether the paper will succeed or sink. There are a few vital requirements in organizing the paper that you can't neglect if you expect to inform and interest your audience.

1. **Make an outline.** What you're going to do is demonstrate your thinking. Do it as you thought it out. You stated the problem clearly, you marshalled the facts, you drew a conclusion. Set up your outline in the same logical sequence and you'll have a strong and sensible structure to build your paper on.
2. **Remember you're giving an oral presentation.** Keep this uppermost in your thinking while drawing up your outline. It's important that you have a strong, appealing opening and a forceful conclusion. Thus you'll attract the attention of your audience, hold it with the logic of your outline and leave the group with a clear and strong impression of your conclusions.
3. **Visual Aids.** These may be a notable factor in your presentation. Plan for them while organizing the paper and remember to allow two to three minutes each for viewing and explaining. Integrate them into the outline of your paper as you would use sketches in an informal discussion to clarify your words.
4. **Writing.** This completes the organization of the paper. There are several helpful rules to guide the author through this phase. I consider them important enough to warrant tacking them up before you as you write:

a. Use short words and short sentences
b. Use direct statements
c. Don't use foreign words
d. Avoid jargon, coined words and trade names like the plague. (Many technical papers have world-wide circulation. A pet, coined word significant in your locality may be meaningless elsewhere.)
e. Words are precise—use them precisely.

At this point you should have a paper written logically, in conformity with the rules of the sponsoring society and which is suitable for oral presentation. To be complete it needs only visual aids.

Illustration

It is more difficult to communicate complex ideas orally than by the written word. When a reader becomes confused he can pause and go back over what he has read until he is better prepared to proceed. Your listener has no such recourse. If you lose him, he's gone forever. You may pick him up again with a forceful conclusion and he may go away impressed but unconvinced. He'll lack conviction because he has not been able to follow the development of your thinking. Visual aids (slides, movies, charts, etc.) can often prevent losing listeners when the thread of argument is tenuous. These aids can also help in reducing masses of data or calculations to one explicit idea.

In addition to its more precise and important functions the visual aid may also be used to achieve a touch of humor or to keynote a talk. A recent outstanding paper on "Research" put the audience at ease and established the motif for the talk with a single slide. It was a color picture of a diaper-clad baby studiously examining his navel and bore the one-word caption "Research."

The visual aid is a keen and powerful tool. It can cut away the fog of doubt, open up new vistas of understanding and appreciation. Unfortunately, careless handling has made it an ineffective bludgeon in too many meetings. One author's guide says "Rather than show slides that are not well made or that cannot be read from the back of the room it is better to eliminate them altogether . . . The showing of poor slides is discourteous to the audience and not only detracts seriously from the meeting but also reflects directly upon the speaker" (1).*

Realizing that no author would knowingly prejudice his presentation with inferior or unreadable visual aids, we have gathered some "do's and don'ts" and helpful hints for the prospective author.

In the general approach to slide presentations:

1. **Don't** use too many.
2. **Don't** present tables on slides—seven lines of type or lettering is considered maximum.
3. **Don't** forget that the conventional slide projector ($3^1/_4 \times 4$-in. slides) requires that the longest dimension be horizontal. (Where the proportions of the illustration and the slide are greatly dissimilar, a mask should be used for proper framing.)
4. **Don't** try to put too much on one slide. Keep it as simple as possible.
5. **Don't** use graph paper for charts or curves. (Simplify the grid and maintain as much open space as possible between grid lines.)
6. **Don't** make up your art work according to publication requirements and attempt to make slides from it. The needs of each medium are very different and you'll be unhappy with results.

And now for the do's . . .

1. **Do** determine the dimensions of the meeting room and the approximate number of conferees expected. You should request a screen size in accordance with the following table: (4)

No. of Conferees	Screen Size
75	70 x 70 in.
75–150	8 × 8 ft
150–300	10 × 10 ft

NOTE: A 10 × 10 ft screen requires a 13 ft ceiling.

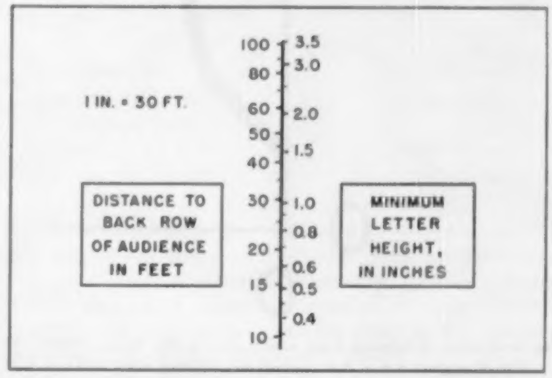


Fig. 1—Minimum size lettering for making charts for any given distance from chart to back row of audience. (Based on 20/40 vision as the control.)

2. **Do** consider the distance from the screen to the last row in requesting screen size and in preparing illustrations. Fig. 1, (5), shows that to be legible in the back row 60 ft from the screen a letter must *at least* be 2 in. high on the screen.

A final note on screen selection—a matte white finish is preferred to a "beaded" screen and may be essential in a wide room where beaded screens can cause distortion.

3. **Do** use large lettering and heavy lines. Figs. 2 and 3 show a typical $3^1/_4 \times 4$ in. slide and a portion of the original from which the slide was made.
4. **Do** make full use of the slide area available. Don't add material to fill—make the illustration larger. Fig. 4 shows basic art work dimensions and slide open area dimensions.
5. **Do** use color to add life, interest and readability to your illustrations. A $3^1/_4 \times 4$ in. glass slide costs about $3.50 in black and white and only $1.50 more in

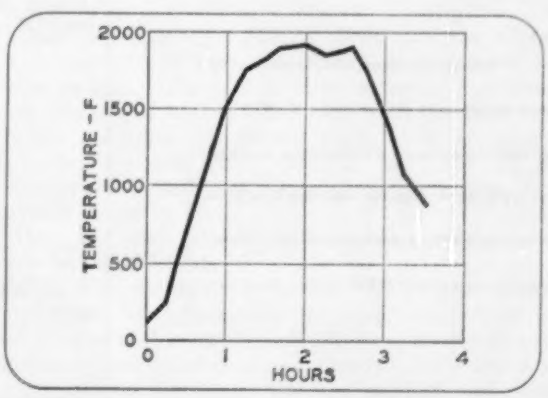


Fig. 2—Actual size reproduction of a $3^1/_4 \times 4$-in. lantern slide with standard mask

* Numbers in parentheses refer to a List of References at the close of the article.

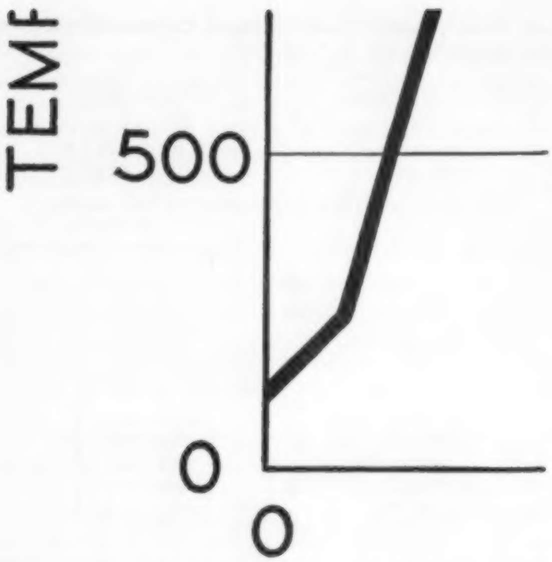


Fig. 3—Portion of original from which slide in Fig. 2 was made. Full size of original is 8 × 9 in. overall and lettering about 9/32 in. high

full color. The effect can be well worth the added cost. Suggested maximum visibility colors are: (6)

a. Black on Yellow	*f.* Black on White
b. Black on Orange	*g.* Blue on White
c. Orange on Blue	*h.* White on Blue
d. Green on White	*i.* Orange on Black
e. Red on White	*j.* White on Black

Harmonizing pastel tints or shades of the same color often are used as effective backgrounds to emphasize different periods of time or other influence in a bar chart.

In the way of helpful hints on visual aids the following tips are too often overlooked:

1. Mark your individual slides with a key number. This can be written on a small label located in the same position, Fig. 5, on each slide. It thus insures that the slide goes into the projector in the proper position as well as identifying it.
2. Carry or ship your slides in a sturdy box marked with your name and session.
3. Allow ample time for a dry run of your presentation and time to change or re-do slides you're not satisfied with.
4. If your presentation calls for a second showing of a slide, *make a duplicate*. Looking back for a slide already shown can throw an otherwise excellent presentation into hopeless disorder.
5. If your material warrants outstanding treatment you should consider the overhead projector. Unusual and extremely effective visual effects with full color and motion of dynamic parts can be achieved. The subject is too comprehensive for coverage in this article but an excellent book on the subject (7) will tell you all you need to know.

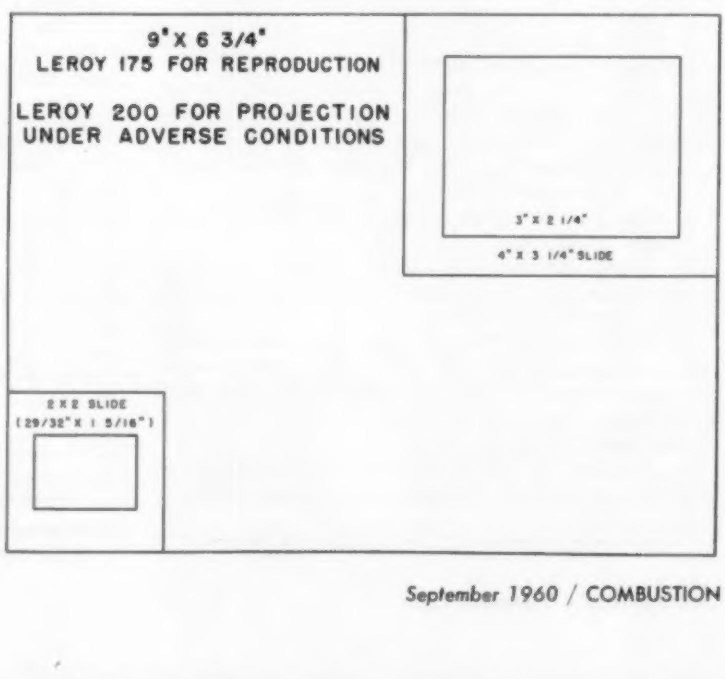
Accommodation

This part of the picture doesn't deal with the author at all. It treats of the sponsoring body and its chairman and vice chairman. The word "accommodate" means to oblige, to furnish, among other things. By accommodation we mean that the chairman and his assistant are *obliged to furnish* to and for the speaker all those things he needs for a good presentation. A host of details must be properly arranged and coordinated so that a paper may be presented in the proper atmosphere. In a well conducted meeting the chairman and vice chairman will concern themselves with the following obligations. These are drawn from an excellent recent book "Organizing the Technical Conference" (Reinhold), by **Herbert S. Kindler**.

An outstanding chairman will select competent speakers and pertinent material and arrange a logical sequence of appearance. He will keep in touch with his authors during preparation of papers to guide and expedite papers. He'll learn enough about his speakers to introduce them properly. Those not generally known to the audience will be *introduced*—well known speakers will be *presented*.

The good chairman will keep his meeting on schedule,

Fig. 4—Actual maximum size recommended for a lantern slide should be the 9 × $6\frac{3}{4}$-in. dimension shown with lettering approximately 6/32 in. high for reduction to a $3\frac{1}{2}$-in column width, upper right, or about 7/32 in. high for projection to a 2 × 2 slide, lower left



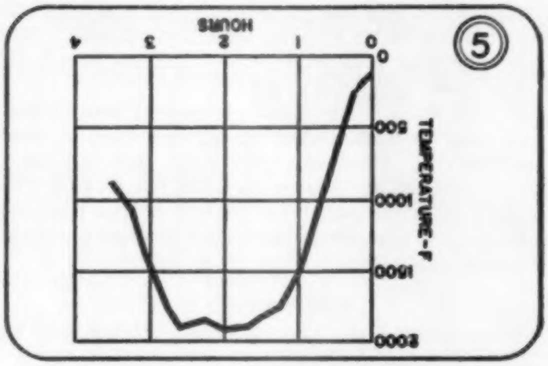


Fig 5—A suggested way of easing the handling of slides is to add a sequence number pasted in the same place on each slide and reading so the slide drawing goes in upside down

free from disturbances and prevent blatant selling, promotion, reminiscing or other abuses of the freedom of speech. He will encourage and regulate discussion, summarize the meeting's accomplishments and thank both the speakers and conferees.

The vice chairman at a good meeting will be even busier according to Mr. Kindler (8). Among other things he must:

1. Learn from the hotel or meeting place management whom to call for emergency services such as power, heat regulation.
2. Arrange for projection operator and his instruction.
3. Limit attendance to properly registered conferees.
4. Ask management not to schedule noisy repair or maintenance work above, below or adjacent to the meeting room.
5. Check direction and door signs.
6. Distribute questionnaires.
7. Check: Projector—focused?—filling screen?—spare bulb?—slides in sequence?—speaker to operator signals arranged?

Room Lighting: switches located—shades adjusted?

Lectern: does reading lamp glare in audience's eyes? prefocused optical pointer handy?—glass and pitcher of water nearby?

Microphones: lectern, lapel, panel table, tape recorder and audience microphones properly located?—adequate extension cords?—amplifier adjusted for good volume and tone?

Supplies: are chalk, erasers, crayons, ice water, ash trays, etc., handy?

Cloakroom: facilities for handling hats and coats sufficient?

Telephone: telephones, Muzak and P. A. systems disconnected?—other arrangements for urgent messages made?

Ventilation: has room been precooled?

There are other duties of a vice chairman it seems, but we'll leave them to a perusal of Mr. Kindler's book (8). Suffice it to say that the sponsoring society must play a large and important part in producing a good paper.

The Presentation

If there is any one point of complete agreement in the field of technical presentations it is this. "What the audience wants is to have the speaker 'tell' his story in a conversational style." (1) (3) This statement appears word for word in the author's guides of several technical societies. In this one sentence we have the keys to a really good presentation.

First of all there is the word "brief." In this area brevity is the cardinal virtue. If you think you can't possibly say all you have to say in the 15 to 30 minutes generally allotted, consider the table below:

Declamation	Time Required
Gettysburg Address . . .	3 min 5 sec
Declaration of Independence . . .	12 min 10 sec
Sermon on the Mount . . .	9 min 25 sec

It seems that it is the brief and to-the-point speech that the world loves. Grant did well at Vicksburg with a one sentence situation summary, "I'll fight it out on this line if it takes all summer." But General McAuliffe did even better with his reply to the German surrender ultimatum at Bastogne—"Nuts."

No one will ever criticize you for saying *all you have to say* in less than your allotted time. Rather they will love you for it and they will be impressed.

The other key phrase in the oft-quoted definition of what an audience wants is "tell his story in a conversational style." Even if one is not considered a good speaker, there can be no excuse for a deadly, dull, end-to-end reading of a paper. Why would anyone spend good time and money to hear a reading of a paper he could more profitably read at home?

The simple truth of the matter is that it's not necessary to be a good speaker to give a good technical presentation. All that is required is to imagine that this is a discussion with an associate. It's a good idea to pick out two or three individuals in different sections of the audience and talk *to* them as you would around a conference table. State the problem, describe the attack, punch home the conclusions—lightening the load with a touch of humor here and there just as you would in a small group. If the speaker knows his subject and has planned a strong outline, the rest will take care of itself. The audience will be treated to a person-to-person type conversation with the speaker. It will gain the benefit of his ideas, his hopes, his dreams perhaps, that may not be sufficiently developed as yet to put down on cold paper. These are the things an audience will come hundreds or thousands of miles to hear. They want facts certainly, but these they can get at home. They also want the little important sidelights, the human angle, some of the information we just don't publish. Give the people what they want and your presentation will be a success. It's that simple.

Here are some ideas to make your speaking task easier and more effective:

1. Prepare a "speaking version" (9) of your paper. This should be shorter than the paper and tailored to suit your available time. Omit history, descriptions of equipment and detail in general except what is essential to follow your thinking. Use the shortest and most direct words and sentences you can think of.
2. Write out this speaking version on 3 × 5-in.

cards with principal ideas in large letters at the top of each.

3. Go over and over these cards in the days before your talk until they become part of you. **Don't try to memorize**—just practice building the headline idea from a glance at the card heading. You may do it in different words every time, but as long as the idea is developed you're well on the way to a good talk.

4. When you get up to speak take a minute to look around at the audience. Pick out the two or three you're going to talk *to*—not *at*.

A man whose composure I had always admired once told me, as I approached a meeting with acute stage fright, to pause a minute, look around at the group and say to myself, "Look you people, if I didn't know more about this subject than you do, I wouldn't be up here." This may not be strictly true in every case but it helped immensely that first time out.

5. If you are using a microphone don't forget it! Put a hand on it if necessary to remind you not to keep turning away from it. If you must move from a fixed microphone to point out something, stop speaking, do your pointing and resume speaking when you return to the microphone.

6: Heed the advice of Polonius and remember, "This above all, to thine own self be true"; when you have finished—stop!! There's nothing more agonizing than listening to a talk that ended ten minutes ago. You've outlined and carded a strong, forceful conclusion. When you finish that your job is done. Express your thanks and sit down to enjoy your reward.

A final word. The outline presented here indicates that some thoughtful effort is required for a successful presentation. There are two things that militate for making that effort. One is the obligation as an engineer to pass on information to the rest of the profession. The other is that the rewards for the effort are greater than you might think.

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(6) "Practical Specifications for Visual Aids," Admaster Prints Inc., New York, 1959.

(7) "They See What You Mean," Ozalid Div., General Aniline and Film Corp., Johnson City, N. Y., 1959.

(8) "Organizing the Technical Conference," Herbert S. Kindler, Reinhold, N. Y., 1960.

(9) "Tuning in With Your Technical Audience," Louis N. Rowley, McGraw-Hill Publishing Co., Inc., N. Y. C.

NCPC Survey Indicates Drop in Residual Oil Demand

An economic survey by the National Coal Policy Conference indicates that total demand for residual oil in 1960 will be about 4 million barrels less than in 1957, the base year for the Oil Import Controls Program, Joseph E. Moody, NCPC president, said in a recent letter to Secretary of Interior Fred A. Seaton.

Mr. Moody said this study showed that Fourth Quarter import quotas based on the 1957 Fourth Quarter levels of about 400,000 barrels per day would insure an adequate supply of residual to meet all foreseeable demands along the East Coast for the rest of the year. Only residual imported into Region I, is subject to control.

"Available data clearly shows that the need for imported residual oil on the East Coast during the Fourth Quarter of this year will not exceed the level of imports in 1957—the base year established by the President's original Proclamation—and we trust that the Oil Import Administration intends to maintain levels no higher than that during the next three months," Mr. Moody wrote Secretary Seaton.

The NCPC study found that no shortages have developed during the year to date, despite contention of some importing interests that shortages were threatened, and pointed out that a recent 15-cents-per-barrel price increase in residual put into effect by the Esso Standard Oil Company was not based on any shortages or indications of such shortages.

"It should be noted that, despite these announced price increases, residual oil in District I is still selling generally below posted prices, and that both posted and actual prices now in effect are considerably below those of this period in 1957," Mr. Moody declared.

The NCPC study of probable demand for the entire year showed that four major categories of use will show a combined decrease of about 23 million barrels from 1957, and that two others will show increases of some 19 million barrels.

These six major categories, and requirement changes since 1957 are:

1. **Industrial:** Requirements down five million barrels, largely due to increasing competition from natural gas.

2. **Oil company fuel:** Off four million barrels, as refineries tend to use more natural gas, refinery gas and petroleum gas.

3. **Non-bonded bunker fuel:** Down 10 million barrels. One explanation for the sharp decline in this business in the past two years is that residual produced domestically and previously sold to vessels in foreign trade is now being reserved for customers requiring non-bonded fuel, while ships' bunker fuel is being supplied by imported bonded fuel not subject to import quotas.

4. **Military, other than exempt re-exports:** Decline of four million barrels.

5. **Heating:** Possible increase of 15 million barrels in 1960, above 1957. It is difficult to obtain dependable current information on this market, but we have allowed for an increase of five million barrels yearly.

6. **Electric utilities:** Increase of four million barrels. This is a particularly difficult category in which to reach conclusions as to probable demand. Many of the larger utility plants have multiple burning equipment, and demand is merely a matter of price per Btu used; without "dump" prices for residual they usually burn coal, or, in some regions, natural gas.

Abstracts from the Technical Press—Abroad and Domestic

(Drawn from the monthly Technical Bulletin, International Combustion, Ltd., London, W. C. 1)

Fuels: Sources, Properties and Preparation

Chemical Structure and Properties of Coal XXVI—Studies on Artificial Coalification. J. P. Schumacher, F. J. Huntjens and D. W. van Krevelen. *Fuel* 1960, **39** (May), 223–34.

By hydrothermal carbonification of plant material and peat the natural coalification has been imitated. Cellulose thus treated in an acid medium is similar to vitrinites, lignin to micrinite, wood to vitrinite. When treated in an alkaline medium, cellulose, wood and peat become similar to natural asphaltites.

Remarks on the Study of the Pyrolysis of Bituminous Coals by Differential Thermal Analysis. A. F. Boyer and P. Payen. *BrennstChemie* 1960, **41** (Apr.), 104–6 (in German).

The sharp rise in the curves of a differential thermal analysis of swelling coals between 420 and 450 C is believed due to a sudden increase of the thermal conductivity of the coal at the moment the coal particles flow together.

The Suitability of Home-produced and Foreign Fuels for the Operation of Slagging Furnaces. Bituminous Coal: Pt. 2. T. Geissler. *Energie* 1960, **12** (Apr.), 136–47 (in German).

The following are discussed: (1) Influence of slagging furnace design; (2) Influence of burner design; 3. Flame temperature in the slagging furnace; (4) New characteristic coefficients for the different designs of slagging furnace. Examples are given of the application of the previously developed (see abstract 5635) and the new coefficients to estimating whether a coal is or is not suitable for slagging operation.

Willington Power Station. Anon. *Iron & Coal Tr. Rev.* 1960, **180** (Apr. 15), 867–8.

The coal supplied to this power station consists mainly of 2″ × 0 slack and an admixture of slurry so that its moisture content may reach 25 per cent. For this reason vibrators and vibratory feeders have been installed at all important transfer points, such as the wagon tipplers, bunker outlets and the grid covering the reclaiming hoppers.

Pressurization of Granular Solid Fuels. M. N. Aref. *ASME Preprint* No. 59-A-150 1959 (Dec.), 12 pp.

The advantages and disadvantages, especially power loss, wear and sealing are compared of: (1) Lock hopper; (2) Lock hopper with a moving wall; (3) Positive displacement ram pump; (4) Solid extrusion; (5) Slurry pumps; (6) Positive displacement gear pump; (7) Multistage centifugal compression with air; (8) Peristaltic or rubber pumps.

Steam Generation and Power Production

Assessment of Resistance to Brittle Fracture in Pressure Vessel Design. Pt. II. K. Schaar. *Tech. Überw.* 1960, **1** (Apr.). 159–64 (in German).

The conclusions with regard to steel selection, design and construction of pressure vessels are set out.

Prediction of Creep Failure Time for Pressure Vessels. F. P. J. Rimrott, E. J. Mills and J. Martin. *ASME Preprint* No. 60-APM-7 1960 (June), 6 pp.

The creep-failure time for a thick-walled pressure vessel is defined as the time at which the true creep strain reaches infinity and used to predict the time to fracture. The solution is presented in the form of graphs. Simplified solutions for very thin-walled and very thick-walled vessels are presented.

Recent Boiler Design Practice. W. H. Rowand and E. G. Kispert. *ASME Preprint* No. 59-A-176 1959 (Dec.), 31 pp.

A review of American Babcock and Wilcox designs dealing with: (1) Jet ignition grate; (2) Mills; (3) Burners; (4) Cyclones; (5) Coal feeders and distributors; (6) Wall constructions; (7) Drum and drum internals; (8) Natural circulation and once-through boilers of which 18 different designs are shown.

Steam Generators. A. Bachmair. *B.W.K.* 1960, **12** (Apr.), 144–5 (in German).

In Germany 61 per cent of boilers above 335 klb/h output are of forced flow design and the largest on order for firing by bituminous coal is a Benson boiler rated at 1100 klb/h at 3000 psi and 990 F. Controls for these boilers have been improved so that they are no longer at a disadvantage compared with natural circulation boilers. Average output has risen from 400 to 465 klb/h, average efficiency is 90.3 per cent pressures vary between 2200 and 3000 psi. One supercritical boiler rated at 4400 psi, 1120 F is in operation, another rated at 580 klb/h, 4630 psi and 1040 F under construction. Although 19 boilers with steam temperatures above 1100 F are operating new orders did not exceed 1040 F. Prefabrication of boiler parts and gas-tight casings are making progress.

Removal of Slag Deposits from Screen-type Superheaters by Vibration Methods. L. I. Kropp and D. L. Itman. *Elekt. Stantsii* 1960 (Mar.), 2–7 (in Russian).

The paper deals with the application of the method to a 160 t/h, 120 kg/cm², 500 C boiler; the vibration device is described and a test and its results are discussed. The working conditions of the metal are considered. The method effectively ensures long-period non-slagging operation and substantial reduction in ash deposits. Regular operation of the vibration equipment considerably increases the heat absorption of the screens. The screen heating surfaces can be kept clean in a gas-flow temperature up to 1350–1400 C and boiler efficiency is improved.

C.E.G.B. abstract.

Designing Boilers for Gas-cooled Reactors. B. G. Ediss. *Nucl. Pwr* 1960, **5** (May), 101–4.

Ways of reducing the work involved in calculating the most important dimensions of a boiler associated with a nuclear reactor using standard methods of heat exchange design are outlined.

Liquid and Gaseous Fuel Firing

Industry's Battle with Fuel Ash. R. C. Bellas. *Power* 1960, **104** (Apr.) 83–8.

A brief review of the causes of oil ash attack in boilers, gas turbines and diesel engines and of the countermeasures available.

Boiler Problems Associated with Use of Bunker C Fuel. J. J. McMullen. *Combustion* 1960, **31** (Apr.), 42, 46–7.

Deposit formation on high and low temperature boiler surfaces caused by the ash constituents of Bunker C oil are discussed. It is contended that washing of the oil to reduce the sodium content and the addition of water-soluble magnesium sulphate to the washed oil at a ratio of 3:1 Mg/V would solve most of the problems. Experience in ships with gas-turbines and oil fired boilers is cited where the effect of these measures has been pronounced.

Water Wash of Bunker C Retards Boiler Slag on Atlantic Tanker. W. A. Walls and W. S. Proctor. *Combustion* 1960, **31** (Apr.), 43–5.

In the American S/S Atlantic Seaman operating at a steam temperature of 1020 F at the superheater outlet slagging difficulties in the superheater were experienced. When using specially prepared oil containing up to 250 ppm of V but less than 10 ppm Na no slagging was found. An oil washing plant has now been installed on board ship to enable all bunker C oils to be used; experience after 6 months has been excellent.

What Oil Burning System for the Automatic Package Boiler? P. D. Goggin. *Pwr Engng* 1960, **64** (Apr.), 76–7.

The advantages and disadvantages of various types of burner (rotary cup, air atomizing, steam atomizing, mechanical pressure) for installation in different kinds of packaged boilers are discussed.

Furnaces and Combustion

Dimensionless Coefficients of Mixture Formation in Combustion Chambers. Pt. V. W. H. Fritsch. *Energie* 1960, **12** (Apr.), 156–61.

The determination of the coefficients of mixture formation is illustrated for: (1) Pressure and rotating-cup burners; (2) Pulverized coal fired cement furnaces; (3) Pulverized coal fired steam generators.

Water-Side Corrosion and Water Treatment

Feed Water Treatment. K. Wickert. *B.W.K.* 1960, **12** (Apr.), 155–6 (in German).

German experience during the past year has shown that difficulties in complete demineralization plants treating surface water can be overcome by using strongly basic exchangers. Since these strangely basic resins are sensitive against surface and pore fouling by iron salts and organic substances they must be frequently regenerated with a 10 per cent sodium chloride solution and flushed with caustic soda. The water has in many plants to be preheated to 100 F to obtain the desired effect. Evaporators supply water of a purity equal to demineralizers. Condenser tubes should no longer be made of copper; aluminum has proved superior.

Corrosion Prevention by the Deoxygenation of Water by the Desorption Method. P. A. Akol'zin. *Corrosion* 1960, **16** (Apr.), 114–6.

A Russian method of freeing water from oxygen dissolved in it is described in which the oxygen diffuses into a gas (free of oxygen) mixed with the water in an ejector. Water and gas are subsequently separated in a desorber. The results of tests are given in a series of graphs.

Tests on the Corrosion Resistance of Russian 12 XM Steel in Distilled Water at 330°C and 130 kg/cm². V. V. Gerasimov and A. I. Gromova. *Teploenergetika* 1960, (Apr.), 42–7 (in Russian).

The method and results of an investigation into the corrosion mechanism and corrosion resistance of a low-alloy steel subjected to the action of distilled water saturated with oxygen, with air and with the addition of hydrazine, at 330 C and 130 kg/cm², are discussed. Results obtained with other steels and drawn from American and Russian literature sources are quoted. *C.E.G.B. abstract.*

Embrittlement A Modern Menace. O. H. Preis. *Pwr. Engng* 1960, **64** (Apr.), 68–9.

It is pointed out that embrittlement of steels used in boilers is still occurring quite frequently although the causes and remedial measures have been known for a long time. The existence of embrittlement condi-

tions can be detected by an embrittlement detector containing a test piece and the feeding of sodium nitrate or coordinated pH-phosphate control prevent embrittlement.

Gas-Side Corrosion and Deposits

Investigation of Corrosion Damage in Slagging Furnaces. K. Baatz, K. Späh and H. W. Thoenes. *Tech. Überw.* 1960, **1** (Apr.), 156–8 (in German).

Two cases of corrosion damage on the gas-side of slagging furnaces are described and discussed. The water-soluble fraction of the deposits contained sulfates and chlorides which determine at higher temperatures the rate of corrosion, but a reducing influence is also likely to have taken part in the reaction.

Power Generation and Power Plant

Large-Scale Power by Direct Conversion. B. C. Lindley. *Engineering* 1960, **189** (Apr. 22), 567–9.

Possibilities of direct conversion of heat (1500–3000 C) into electricity are considered. These are: (1) Thermoelectris; (2) Thermionic; (3) Magnetohydrodynamic. Design considerations are presented.

Experiences with Gas Turbines in French Power Stations. P. Chambadal. *ASME Preprint* No. 60-GTP-1 1960 (Mar.), 11 pp.

Gas turbines and free piston generating plants have been installed in several French power stations to meet peak load demands. The problems of using heavy fuel oils and remote control are discussed in some detail.

Gas-Steam Power Generation. P. T. Martinuzzi. *ASME Preprint* No. 60-GTP-6 1960 (Mar.), 12 pp.

The possibilities of a gas turbine producing power and its exhaust generating steam for a steam turbine have been examined and the efficiency of such cycles calculated. The study has been extended to include closed-cycle gas-steam power generation in connection with a high-temperature gas-cooled nuclear reactor. The results of these calculations are given in tables.

Gas-Turbine-Exhaust Heat-Recovery Cycle. G. L. Morris. *ASME Preprint* No. 60-GTP-9 1960 (Mar.), 8 pp.

Various schemes of gas turbine, waste-heat recovery and separately-fired boilers were considered to provide an industrial plant as efficiently as possible with 64500 lb/h steam at 425 psi and 500 F, additional to auxiliaries and starting turbines for the gas turbines and 100,000 lb/h of deaerated water at 550 psi for process. The optium solution was found to be the installation of two 7500 hp gas turbines for driving process equipment, two 30,000 lb/h pressurized waste-heat boilers with stack economizer for feedwater heating and a separate economizer for process water and two 40,000 lb/h water-tube oil fired boilers using either air or turbine exhaust gas for combustion. The heat balance calculations are presented.

Economics of the Steam-Gas Turbine Exhaust-Fired Cycle for Medium-Size Utilities. M. Eisler and W. M. Sybert. *ASME Preprint* No. 60-GTP-15 1960 (Mar.), 9 pp.

It is suggested that in many smaller networks the addition of a gas turbine exhausting directly into a steam generator will save considerable capital costs compared with a complete new unit. The results of calculations for various sizes of networks are tabulated assuming an average annual peak load growth of 8 per cent.

How Deere Plant Pressure-Fires a Spreader-Stoker Installation. H. H. Reisman. *Pwr Engng* 1960, **64** (Apr.), 89–91.

The advantages of pressurized firing are briefly enumerated and the special design details required for pressurizing described. The lower part of the boiler is surrounded by an airtight enclosure with revolving door. The fd fan passes the air to the windbox from which it flows through the grate in volumes controlled by a damper. Sufficient coal is kept in the duct from bunker to hopper to prevent outward leak of air. Overfire air is taken from the ash pit and injected from the rear. The ash pit has its own enclosure and door and the ash is removed pneumatically. At an average load of 87,000 lb/h the boiler efficiency has been 85.64 per cent with a CO_2 of 12.8 per cent when firing coal of 10 856 Btu/lb.

Ferrybridge B-300 Mw Station. Anon. *Elect. Times 1960*, **137** (May 5), 722-4.

This recently commissioned station contains three units each consisting of a boiler rated at 760 klb/h at 1600 psi and 985/953 F and a 100 Mw turbo-generator. Overall building volume is 31 cu ft/kw installed and overall cost of about $137.50/kw installed.

Consider Simplified 100 Mw Generating Unit for Peaking. W. Welch. *Elect. Wrld* 1960, **153** (Apr. 4), 28–31.

The growth of peak load at a higher rate than the average load causes concern to American networks since the supply of this peak load by reheat units designed for high efficiency at full load is very expensive if these units operate at low loads. The Long

Island Lighting Co. is therefore installing a 100 Mw peak load unit of minimum cost. It operates at steam conditions of 850 psi and 950 F, with a single heater for preheating feedwater to 250 F and without air preheater, single full-load pumps for the feed water, condensate and circulating water. The boiler has a pressurized furnace fired by heavy oil to eliminate equipment required for coal-firing and both boiler and turbine are installed out-of-doors and as closely together as practical. The condenser is designed for water at 50 F in winter and the loss of 4–5 Mw output with water at 85 per cent F in summer is regarded as less important. Similar cost reductions have also been effected on the generator and electrical equipment. The total cost of the unit will be about 60 per cent of a 185 Mw reheat unit.

The Second Extension of the Masnedovaerk, Denmark. H. Billeschou. *Elektroteknikeren* 1960, **56** (Mar. 7), 96–106 (in Danish).

The third and final section of the station has a 250 t/h (m.c.r.) Benson boiler with reheat and a 80 Mw three-cylinder double-flow condensating turbine driving a hydrogen-cooled 100 mva 0.8 p.f. alternator. The boiler house is of light steel construction with 5m × 75 cm aluminium plates assembled at ground level into 15 m^2 cladding sections with fastenings designed for installation from indoor scaffolding. Provision is made for oil and p.f. firing using slurry up to 25 per cent moisture content with mill drying. The condensate circuit has a complete demineralization plant and purification equipment ("politi filter"). The hydraulic ash and fly-ash-removal equipment, feedwater-treatment plant, electrical equipment, and control room and automatic boiler control system are described.

From C.E.G.B. Digest 1960, **12** (May), 1274.

New Stockholm Plant Generates 80 Mw of Power and Heating for 60000 People. Anon. *Pwr Engng* 1960, **64** (Apr.), 80-1.

The plant contains three boilers supplying steam at 1100 psi and 970 F to three turbines. The steam from two of the turbines is condensed by heating the water for the district heating system to 155–250 F, the third turbine has a regulated bleed point for water heating. Hot water is stored in three accumulators and two expansion tanks under air pressure and distributed to consumers over three miles away. Coal is stored partly below and partly above sea level in a basin forming also the unloading dock.

Materials and Manufacturing Processes

The Electron Theory of Metals. B. L. Mordike. *Research* 1960, **13** (May), 179–86.

The new theory is described by which it is possible to explain conductance, semiconductors and the theory of alloys.

Steels for Energy Plants. K. Kreitz. *B.W.K.* 1960, **12** (Apr.), 142–4 (in German).

A review of recent developments in steel compositions for temperatures between 1000 and 1100 F, 1100–1200 F and for higher temperatures, connections between ferritic and austenitic steels, of standards and specifications, of basic research, cast austenitic steels and relaxation.

Electric Furnace Steel for Nuclear Applications. C. Jamieson and J. Mowat. *Nucl. Engng* 1960, **5** (May), 207–11.

Preliminary data are tabulated to show that steel produced in electric arc furnaces is likely to have improved properties for nuclear reactor applications than o.h. steels. Creep test data are not yet available.

Stress Corrosion of Austenitic Stainless Steel by High-temperature Solutions and Contaminated Steam. P. P. Snowden. *J. Iron & Steel Inst.* 1960, **194** (Feb.), 181–9.

The investigations concerned stress corrosion in 18–9 Nb-stabilized steel exposed to chloride and caustic solutions at various stresses and temperatures. The rate of attack depended on stress level, solution strength and temperature. Specimens contaminated with chloride and caustic were exposed to high-temperature, high pressure steam. The attack by sodium and potassium hydroxides can be either inter- or transcrystalline. Additions of sodium phosphate or nitrite greatly reduced the rate of attack.

The Aging of some Russian Austenitic Boiler Steels. I. N. Laguntsov and V. F. Zlepko. *Teploenergetika* 1960, (Apr.), 38–42 (in Russian).

Test data are given relating to the change in impact strength, hardness and elongation of three Russian boiler steels after aging for periods up to 15,000 h; all three showed considerable change in properties after aging. Embrittlement during aging did not reduce the impact strength below a dangerous level.

C.E.G.B. abstract.

Instruments and Controls

A New Ultrasonic Test Instrument for Boiler and Apparatus Construction. V. Deutsch. *VDI-Z.* 1960, **102** (Apr. 21), 457–8 (in German).

A new instrument is described which enables to test steel plates and welds of more than 5 mm thickness with great accuracy. The instrument is put on wheels to facilitate making tests in less accessible places.

Cyclone O_2 Analysis Checks Combustion Efficiency. J. J. Osochowsky and E. A. Schempp. *Power* 1960, **104** (Apr.), 92–4.

A water-cooled probe able to withstand gas temperatures of 3000 F has been developed which can be installed at the outlet of the cyclone throat and allows continuous monitoring of the O_2 content of the combustion gases. It is hoped to develop from this an automatic control system for the optimum adjustment of the fuel and air ratio at all operating conditions.

Nuclear Energy

AEC Puts Together a Long-Range Power Reactor Program. Anon. *Nucleonics* 1960, **18** (Apr.), 71–82.

The program put forward to make nuclear power economic by the year 1968 is outlined. Research is to be concentrated on large reactors of around 300 Mw size and the 8 reactor concepts, their capital and power costs are presented. These include the pressurized water, boiling water, organic-cooled, sodium-graphite, gas-cooled, fast breeder, aqueous homogeneous and heavy-water moderated reactors. The main problems concerning the development of each type are set out, common to all are further developments in fuel elements.

The Instability Problem in Gas-Cooled Reactors. A. Fonda. *Nucl. Pwr* 1960, **5** (May), 93–6.

In addition to instability caused by temperature and xenon poisoning the control system may also cause instability if the control parameters are inappropriately chosen. The control system studies of the C.E.G.B. and the results obtained of kinetic response to three different control settings are described and discussed.

Small Power Reactor Survey. J. S. Burkett. *Nucl. Pwr* 1960, **5** (May), 97–100.

A brief survey of small reactors available or planned in U.S.A., Gt. Britain, Germany, Italy and Switzerland.

Even Smaller Reactors. Anon. *Engineering* 1960, **189** (Apr. 15), 515–6.

A review of small American stationary and portable reactors.

Study of 4 BWR Concepts Shows One-Unit 300-Mw Plant Feasible.

H. C. Ott and R. H. Gordon. *Electr. Wrld* 1960, **153** (Apr. 4), 33-6, 80, 82, 84.

The four cycles considered are: (1) NIS natural circulation with internal steam separation; (2) NES natural circulation with external drum for steam separation; (3) FSC forced circulation with external drum; (4) FDC forced circulation, dual-cycle with external drum. Calculations were made for a 200 and a 300 Mw unit which showed the FDC cycle 300 Mw unit to be the most efficient and able to produce 1 kwh at 1-1½ mill higher cost than a coal fired unit at a fuel cost of 35 cents per million Btu. Development of nuclear superheating has not yet been developed sufficiently to be taken into consideration and fossil fuel superheating does not show an advantage. Improvements may be obtained by combinations of natural and forced circulation.

A Closer Look at the Real KIWI-A. Anon. *Nucleonics* 1960, **18** (Apr.), 96.

A few details are given of the design of this reactor, a prototype built for use in nuclear rockets. The core consists of graphite fuel plates impregnated with uranium, cooled by hydrogen and with control rods in the centre. The performance of the reactor is still classified.

Grinding, Screening and Filtering

Test on a Tubular Ball Mill Pulverizing System for Low-grade Coal with Supplementary Fanning of Oversize Product. S. P. Tsigankov. *Elekt. Stantsii* 1960, (Mar.), 10–17 (in Russian).

Supplementary fanning of the oversize product of low-grade coal in tubular ball mills improved the performance only for screen $R_{88} > 6^1/_2$ per cent with a gravity type classified and $R_{88} > 7^1/_2$ per cent with a centrifugal classifier. For $R_{88} = 12$ per cent an improvement in performance of up to 13 per cent and a power saving of up to 5 per cent were obtained with a gravity-type classifier; the improvement was only $6^1/_2$ per cent, with increased power consumption, with a centrifugal classifier. In some cases, supplementary fanning can also improve the performance of tubular ball mills for pulverizing hard coals or other types of coal.

C.E.G.B. Abstract.

Fuels: Sources, Properties and Preparation

Carbonization Studies. Fluidization Technique. Anon. *Coal Res. in C.S.I.R.O.* 1960, No. 9 (Feb.), 2–7.

The laboratory plant with a carbonizing capacity of 50 lb/h of coal is

described and some of the results obtained with air or recycle gas at 400–700 C are tabulated. The char is to be used for blending with coals to produce a high-quality metallurgical coke, the tars as a base for a variety of chemicals.

Materials Handling. J. R. Arwood and R. W. Wesson. *Ind. Engng. Chem.* 1960, **52** (Feb.), 181–8.

The annual review of literature published in 1959.

The Application of Vibratory Power to Mechanical Handling. J. D. Latham. *Mech. Handl.* 1960, **47** (Mar.), 132–5.

Applications of vibratory power, based on a rotary motion (Vibromotor), to the handling of a wide variety of materials are described.

Operating a Coal Storage Area with a Mechanical Shovel. J. Oliver. *Bull. d'Inf. des Centrales Electriques* 1960, **27** (Jan.), 15-19 (in French).

When the coal yard equipment (a bulldozer and a scraper) were due for replacement, consideration was given to the use of a mechanical shovel and its advantages over the former system are demonstrated and the method of working is explained. The main reason for this is due to the nature of the coal storage area and the fact that a number of different quality coals are stocked. Over large distances in a yard served by fixed installations and storing only one quality of coal the scraper has the advantage.

From *C.E.G.B. Digest* 1960, **12** (Mar. 26), 765.

Hydraulic Transport of Lump Coal. Anon. *Fördern u. Heben* 1960, **10** (Feb.), 91–3 (in German).

The essential details of a Russian article are translated. The investigations concerned the transport of large coal pieces by a suspension of fine coal in water, the relationship between concentration of fines in water and size of coal transported, frictional resistance and wear. Cost of transport by this method is only $^2/_3$ to $^1/_2$ of that by railway.

Steam Generation and Power Production

The Assessment of Safety against Brittle Fracture in Pressure Vessel Design. Pt. I. K. Schaar. *Tech. Überw.* 1960, **1** (Mar.), 101–8 (in German).

The revised German standards for carbon steels with regard to their brittle fracture performance is explained and the application of these standards to steels for pressure vessels discussed. The physical basis, the influence of notches, residual stresses, temperature, rate of deformation, for-

eign atoms and the significance of the notch impact test, transition temperatures and susceptibility to aging are presented.

The Edge Value Problem in the Calculation of Thermal Stresses in Reactor Pressure Vessels. D. Raday. *Atomkernenergie* 1960, **5** (Feb.), 53–7 (in German).

An equation is derived for calculating the stresses caused by the differential thermal expansion of the cylindrical shell and the semi-spherical ends. The validity limits of the boiler formula are given.

Sulzer Steam Boilers. H. Vogler. *Sulzer Tech. Rev.* 1959, **41** No. 2, 57–73.

The development of steam generators from the first built in 1841 to the latest monotube boiler of 750 klb/h at 2420 psi and 1110/1060 F is described.

Steam Generators for the Paper Industry. Anon. *Energie* 1960, **12** (Feb.), 74-5 (in German).

Two boilers are described both rated at 149 klb/h at 1950 psi and 975 F with reheat to 825 F. One of the boilers includes a slagging furnace for the firing of pitch coal, bituminous coal and oil and an upper radiant furnace with additional oil burners; the upper part of the walls of the radiant furnace are superheater surfaces. The reheater is installed in the damper controlled convection pass. The Ljungstrom air preheater is of the two-stage type and has an air bypass to increase the flue gas temperature from normally 320 F to 375 when burning fuels of high S content. The other boiler is exclusively oil-fired with the burners in the front wall and radiant superheater in the front wall.

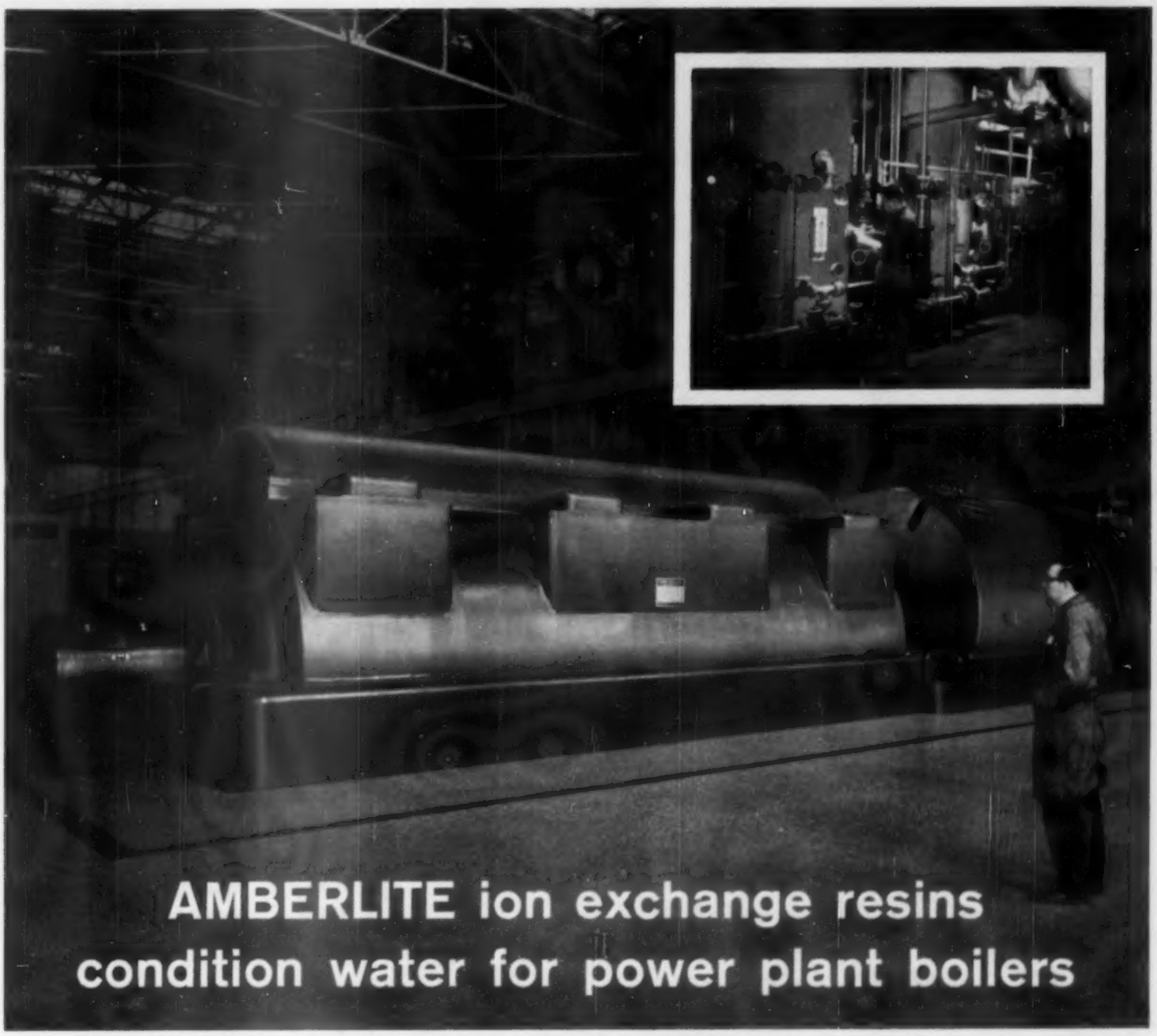
Damage to Superheaters and Preventive Measures—Part 1. R. Malicet. *A.P.A.V.E. Bull.* 1960, **41** (Jan.), 3–35 (in French).

A number of superheater tube failures that have occurred during operation are described. These are divided into the following categories: those due to (*a*) the composition of the boiler water, (*b*) the result of increase in steam temperature, (*c*) irregular circulation, (*d*) external erosion, (*e*) shut down of plant, and (*f*) manufacturing faults. Some thirty cases are described and discussed.

From *C.E.G.B. Digest* 1960, **12** (Mar. 26), 759.

Distortion of a Radiant Superheater Panel. J. Simonne. *Bull. d'Inf. des Centrales Electriques* 1960, **27** (Jan.), 30–4 (in French).

The radiant superheater of a 400 t/h boiler was found to deform and break loose in the burner zone.



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(Continued on page 67)

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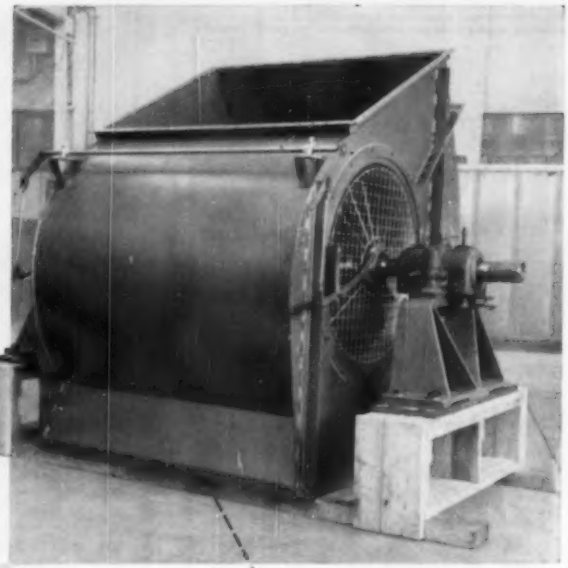

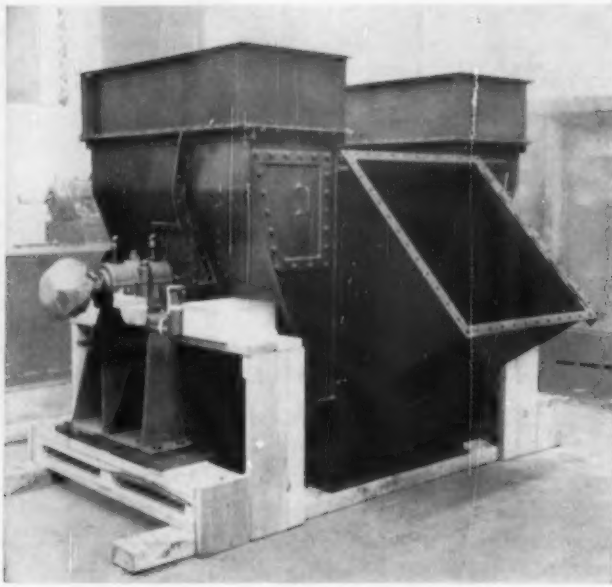

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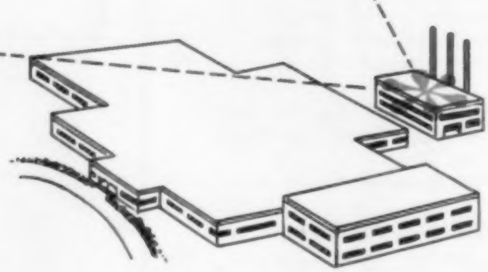

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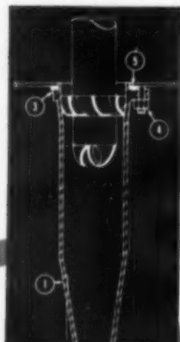

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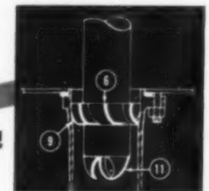

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